Development of a motivational tool used for cancer patients to increase their physical activity with focus on front-end

Faris Michael Halteh
Abstract

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Cancer patients who undergo chemotherapy and other treatments tend to become weary, depressed and will inevitably lose a great amount of muscle mass due to said treatments and decreased activity levels. Consequently, extensive research was done on how physical activity can combat the adverse effects of these treatments. Physical activity is not only safe and doable for cancer patients, but it can also increase their quality of life, their physical performance and reduce the duration of hospitalisation.

As a result, the Center for Technology in Medicine and Health (CTMH) wanted to tackle this problem by developing a motivational tool that uses a sensor to retrieve measurements about the patient’s movement levels. Retrieved data then gets processed on an Android application to provide instant personalised feedback about the progress of the patient in a visual format. This tool illustrates the potential for an application to motivate cancer patients to reach a moderate physical activity level by quantifying their movements.

This thesis is focused on a comparison study to compare wearable devices that can measure the patient’s activeness, in addition to the design and development of a graphical user interface (GUI) for this tool.
Acknowledgments

I would like to express my acknowledgement and appreciation for the great and outstanding team at the Centre for Technology in Medicine and Health (CTMH) that I was working with during the development of this motivational tool. Without their guidance, uplifting spirit and ongoing help, this thesis project would not have been possible.

I would also like to thank the physiotherapist Nina Nissander who helped us talk to patients throughout the development. I am very grateful for all the patients staying at the haematology department in Karolinska Institute’s hospital who were willing to take the time to talk to us, give us feedback about the product and participate in all the testing sessions that have been conducted.

I am also indebted and grateful to Edith Ngai for her interest in the project and for being a great reviewer, giving instant feedback and guidance throughout the way.

Last but not least, I would like to thank God for giving me the ability to complete this project. And I can’t forget to give my special gratitude to my family and friends, who have always been supportive and loving.
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Preface

This master thesis project was carried at the Centre for Technology in Medicine and Health, CTMH. The supervisor at CTMH who provided guidance to this thesis was Håkan Maclean. CTMH is a cooperation between The Royal Institute of Technology (KTH), Karolinska Institutet (KI) and Stockholm County Council (SLL). This cooperation’s vision is to help develop the Stockholm region as a world-class medical technology centre. "As a portal, CTMH creates venues and activities that stimulate and develop exchanges between industry, academia and health care in the boundaries between technology and health, research and application" [11].

This project was developed in a team with four other team members who had separate roles in the project. All interviews, usability testing sessions and user studies were performed at Karolinska University hospital in Huddinge, Sweden.
Part I

Project Introduction
Chapter 1

Introduction

This chapter introduces the problem and gives a brief overview of the aim of this research. This is followed by the tools and technology used in this project.

1.1 Background

Although the road of surviving cancer is not an easy one, physical activity can radically ameliorate this road and help patients overcome this unfortunate period in their lives. Patients who get treated for blood cancer (leukaemia) undergo strenuous chemotherapy treatment regimens that often leave them weary and tired, experiencing physical and psychological stress [50, p. 321].

Chemotherapy and stem cell transplantation can have pernicious effect on patients’ quality of life. Several psychological, physical and psycho-social problems occur before, during and after the treatment. These problems include emotional problems caused by distress, lack of physical activity, immunological changes and many more [50, p. 321]. Other symptoms including fatigue and impairment of physical performance are also quite common among cancer patients [13, p. 3390].

Nevertheless, numerous studies have revealed that physical exercise such as aerobic exercise is not only safe and feasible during cancer treatment, but it can also result in significant benefits for patients undergoing chemotherapy and stem cell transplantation. In a study that was conducted to investigate the effect of physical activity on patients receiving stem cell transplantation in Germany, aerobic exercise programs were introduced. The study revealed that exercise interventions have resulted in significant positive impact on the patient’s quality of life, physical performance and
fatigue status. In addition, another observation that was mentioned in this study is that immune cells were recurring faster for patients who followed the exercise programs [50, p. 321]. In another study that was aimed to prevent the loss of physical performance for cancer patients by introducing an exercise program consisting of biking, it was found that aerobic exercise can be safely performed directly after high-dose chemotherapy. Moreover, the hospitalisation period was shorter for the group of patients who received training in this study [13, p. 3394].

Although physical exercise can significantly increase cancer patients' wellbeing and quality of life, physiotherapists and doctors find it difficult to motivate patients to be active by walking, cycling or doing aerobic exercises instead of being immobilised in hospital rooms. Thus, this presents a tremendous problem for both staff and patients [41].

1.2 Internet of Things

Internet of Things (IoT) is a concept that is currently changing the world. According to the U.S. National Intelligence Council, Internet of Things (IoT) is defined as "the general idea of things, especially everyday objects, that are readable, recognisable, locatable, addressable, and/or controllable via the Internet, irrespective of the communication means" [10].

One example of IoT that has been changing the world of health and fitness in recent years is activity tracking using sensors, an industry known as "The Quantified Self". This gives people the capability of tracking their own activity levels using sensors and IoT technology, with a general goal of increasing their fitness and becoming healthier. With this technology, people set goals and aim to achieve them. The unique thing about this industry that makes it quite effective in motivating people to be more active is that these tools turn fitness and health into a game. With each goal achieved, the user gets a sense of reward for being more active, which will in turn result in a better health [42, p. 232].

1.3 Aim of the Study

Since numerous studies claim and prove that physical activity has the capability of increasing the wellness and quality of life of cancer patients, the goal of this project
was to design and develop a new motivational tool that would encourage and motivate patients to increase their physical activity using the Internet of Things.

The haematology department at Karolinska Institutet’s Hospital treats cancer patients with chemotherapy treatment programmes that often leave them tired, physically impaired, weary and more vulnerable to infections. For this reason, the goal of this investigation was to develop a highly usable motivational tool in the form of a software that would give patients instant feedback on their activity levels in order to motivate them to increase their physical activity, which will in turn improve their well-being and reduce the hospitalisation period. This tool uses the Internet of Things, by utilising a sensor that retrieves raw data from patients using a low power built-in accelerometer and an android tablet. The data retrieved gets sent to an android tablet that is situated on the bedside of each patient. The data is then processed on the tablet to identify and recognise what activity is being performed by the patient using a machine learning algorithm. Finally, the activity levels get demonstrated in visual format on the android tablet to show patients, doctors and physiotherapists the patient’s activity levels.

1.4 Software Development Tools and Technology

Several softwares were used to design and develop the prototypes that were tested on patients.

1.4.1 The Android Application

The tools used for the development of the motivational tool are described below.

- **Android Studio**
  The Android application was built using Android Studio with a minimum API of 19 (Android 4.4) as the application was built with an aim of supporting Bluetooth Low Energy which was introduced as a built-in platform support in Android 4.3. Android studio is considered the official Integrated Development Environment (IDE) for the development of Android applications [15].

- **Android SDK**
  Android Software Development Kit (SDK) is the SDK necessary to develop
applications for the Android platform. It includes an emulator, debugger, documentation, sample code and libraries that are required to build Android applications [12].

- **Java**
  Java is an object-oriented programming language that was first released by Microsystems in 1995. Java is the programming language used to develop Android applications, and therefore it was used to develop the Android application for this research.

- **Git**
  Git is a powerful tool used as a version control system. Since this application was developed with other team members, it was a perfect tool for collaborative software development with useful features such as working on several branches, rolling back to earlier versions of the code, code history, among others. This project’s repository is hosted at BitBucket, a git code management tool.

- **Lenovo Yoga Tablet 2**
  This Android tablet was used for testing the software on patients. Lenovo Yoga Tablet 2 has a stand that allows the tablet to rigidly stand on a table, which was beneficial for this project as the final product was expected to be located on a table next to the patient.

### 1.4.2 Design and Prototyping Softwares

The tools used for designing the prototypes that were tested on patients (discussed in Section 7.2) and graphics incorporated in the interface are described below.

- **Balsamiq Mockups**
  This software is a wire-framing tool that was used in this project for creating mockups of the interface of the application easily and quickly.

- **Adobe Illustrator**
  Adobe Illustrator was used for designing parts of the interface (both the mockup and the real one) that required graphics and vectors such as icons and charts.

- **Apple Keynote**
  Apple Keynote was used to add interactivity to the mockup screens by adding
hyperlinks between different screens, allowing users to play around with the mockup and give feedback.

- **Invision**
  Invision was also used to add interactivity to the mockup screens to have a non-linear presentation of the interface. This tool allows the user to add hotspots to the static screens to make them more interactive with transitions and animations.

1.4.3 Libraries

- **PebbleKit Android**
  The PebbleKit Android is a Java library that is included in the Pebble SDK. The application uses classes and methods in this library to connect to and communicate with the Pebble device.

- **MPAndroidChart**
  This library is a chart library for android that provides support for creating bar charts, line charts, pie charts and more. The interface of this project has two charts (bar and pie) that were created using this library.

- **Encog**
  This library is a machine learning framework that was used for the support vector machine (SVM) used in this project to recognise the patient’s physical activities.

- **Couchbase Lite Android**
  This library is a lightweight NoSQL database engine that was used for the database implemented for this software.
Chapter 2

Problem Elaboration

This chapter introduces the user study that was conducted at Karolinska University Hospital to get a better understanding of the problem that this thesis aims to tackle and the prospective users of the systems. In addition, based on the user study and design solutions, we present a number of research questions and set the limit of this thesis.

2.1 User Group

This project was targeted to be used for a scientific study that will be conducted by the Center for Technology in Medicine and Health (CTMH) after fully developing the prototype. The study will mainly include cancer patients who are undergoing treatment. Thus, prospective users are not expected to have a high level of interaction with the product. In addition, prospective users have a wide range of computer literacy, hence the application has to be adapted for this matter.

2.2 User Study at Karolinska Hospital

Before the design and the development of the application, it was necessary to conduct a user study in the beginning phases of the project to get a profound understanding of prospective users, their goals, limitations and abilities. This study was conducted to identify the needs of this product and to know how things operate and function without the introduction of the motivational tool being built in this project. The user study was documented and data was collected using observations and interviews
with prospective users such as patients, doctors and physiotherapists at Karolinska Institutet’s Hospital in Huddinge.

2.2.1 Background

The conducted observations and interviews were evaluated to get qualitative information about the environment that will host the product developed in this research. The main objective of conducting this user study was to trigger the initial planning of the project and get a better overview of prospective patients who might be using the motivational tool. The main department in which the study was performed in was the Haematology department that consists of patients undergoing chemotherapy treatment and stem cell transplantations.

The study focused on several primary areas: user background, user capabilities, traditional ways used by the physiotherapists to motivate the patients to move, patients’ conditions and common problems that are faced by patients, doctors and physiotherapists.

The department’s physiotherapist and her colleagues ensure that each patient in the department gets information about the recommended exercises that would help the patients’ immune system and sustain their physical strength during the treatment time. The exercises for each patient varies depending on the patient’s capabilities. To determine the patient’s ability to exercise, a lot of factors are taken into consideration. Patient’s condition, temperature, mood, age and blood samples are examples of such factors. Some patients are quarantined and are obliged to stay in their rooms for long periods during the day due to vulnerability to infections and diseases; consequently, it is vital that they exercise whilst being in a stationary location. The main aim of exercising in this department is to avoid losing muscle mass during the treatment time. In addition, the physiotherapist mentioned that "exercising is highly positive for patients who are receiving stem cells transplants as it can increase the blood circulation which leads to a faster treatment". Patients are also advised to walk outside if they are capable. Moreover, it is recommended for the patients to sit upright to reduce the likelihood of lung infections and pneumonia. Patients who are admitted to the department could be undergoing chemotherapy; having stem cells transplants or admitted due to occurring complications after treatment.

Patients are visited by the physiotherapists on an average of 2 to 3 times per week. The physiotherapist spends approximately 20 minutes with each patient to help her
or him exercise and informs the patient about the importance of physical activity and what exercises she or he needs to perform to get better. Patients are highly advised to exercise unless they are suffering from infections, fevers, low platelet count or low haemoglobin levels. During the user study, we have observed the physiotherapist with four different patients who were undergoing different treatments for different types of cancer.

The condition of the patient is dependent upon several factors including: age, stage in the treatment, type of treatment, physical activity, motivation and pain levels. One patient had no motivation to perform any physical activity due to her status. She felt too tired to perform any activity.

The physiotherapist showed us different aids that can be used to exercise, including rubber bands, dumbbells, bicycles, weight lifting straps, stress balls and balance boards.

2.2.2 Problems

The physiotherapist in this department finds it difficult to evaluate if the patients have performed the exercises and movements that they were asked to do. A common problem in such situations is that patients might not give the correct information to the physiotherapist, leading to inaccurate results while evaluating the effect of physical activity on the physical performance and well being of cancer patients.

Another problem that could be an issue is that not all patients are capable of performing physical activities, thus the goals for each patient have to be specific and personalised to what each patient is capable of doing.

2.2.3 Other Information

After observing patients that are undergoing different stages of treatment, it was concluded that the patient’s mood and motivation to exercise is highly influenced by the stage of treatment in which the patient is going through. The patient who was just admitted to the haematology department was quite motivated and active, walking around the hospital to maintain his health. On the other hand, two of the observed patients were too tired to perform any physical activity.
2.2.4 Design Solutions

This part describes the design for the motivational tool that is aimed to motivate patients to increase their physical activities and help physiotherapists and doctors know more about the patient’s activities. The main focus of the application is to increase the patients’ motivation to move and exercise, as according to recent studies mentioned in this report, exercise during cancer treatment is not only possible and safe, but also increases the well-being of the patients, increases their immunity and reduces the admitted time at the hospital. This application will read data from the sensors and then present the patients’ basic activity levels in a visual format. Physiotherapists will also be able to set specific goals on the application in cooperation with the patient. Another feature that this application will have is to track the mood and the pain level of the patient with a value scale that the patient selects from. To evaluate the overall performance of patients and how well they have done in a particular day, the concept of Activity Points was created and tested on patients. Activity points are simple numbers that keep track of how much each patient moves. The more they move, the more they earn.

2.2.5 Personas

After conducting interviews and observations at the hospital, a few personas were created in order to get a better picture of the prospective users who might be using the developed product.

Patients that were involved ranged from patients who were about to start their treatment to patients who were in their later stages of the treatment (See Appendix A for personas). In general, most patients were significantly tired and lacked motivation to exercise. The physiotherapist has to explain the importance of physical activity before, during and after the treatment time. They all shared a common goal, which is to get better and healthier as soon as possible. The personas were constructed based on information from four patients, a medical doctor and a physiotherapist.

2.2.6 Design Considerations

The majority of patients at the haematology department are quite weary and tired due to the treatment. One design consideration that was taken into consideration was that patients are not expected to be able to make a lot of interactions with the
application, thus it was vital to create a simple application that does not require any mental effort. In addition, physiotherapists and doctors usually do not have a lot of free time and therefore it was important to have an application that shows an overview of the patient’s progress in a fast efficient way.

Another thing that was revealed during the user study was that in certain cases, patients might not be able to use the application; hence we had to consider that the users of this application could range from patients, physiotherapists, doctors, nurses, relatives to friends who are interested in knowing more about the physical activity, performance and progress of the patients.

Due to limited time and budget, the first version of the application was developed to give a visual representation of the following quantified activities:

- Active
- Inactive
- Standing
- Sitting

2.3 Research Questions

The following research questions will be addressed in this thesis:

1. What are the existing wearable devices that encompass built-in sensors that can be used in a hospital setting to retrieve data such as body movements and heart rate from patients?

2. What are the current available motivational tools that motivate patients to move more?

3. How will the activity levels of each patient be represented on the tablet to motivate patients?

4. How usable is this application for physiotherapists, doctors and patients?
2.4 Contributions

The first contribution of this thesis project was to examine available wearable devices that can retrieve body movements and interview hospital staff to get their recommendations about the chosen device. Several requirements were set to help us choose a proper wearable device that can be used in a hospital setting without interfering with the patient’s care.

The second contribution was the design and development of an Android application that helps cancer patients to increase their physical activity levels. The design and development have been done in a user-centric way close to patients and hospital staff. After every design iteration, we have conducted usability testing and interviews to ensure that patients are able to understand our product and help design a better interface. The resulting application presented in Chapter 9 has been tested on six patients for one day as a part of the evaluation discussed in Chapter 10. Although the application is considered a proof-of-concept only, it has gained high acceptance in the haematology clinic which opens doors for further development and research in this domain.

2.5 Delimitations

It was quite difficult to engage prospective users in the design and development stage due to their health conditions. Each usability testing / interview was conducted with an average of three patients, which might not have been enough. Thus, these sessions could be more accurate and collect more constructive qualitative feedback if a minimum of five participants were involved in every session.

Another delimitation of this project is that due to limited time and resources, we had to use a wearable device that already exists in the market for collecting patients’ measurements. However, these devices are often equipped with a number of extra sensors that are not needed for this project. Thus, for a future iteration of this system, it seems more appropriate to design and develop a new wearable solution that is specifically created to meet the requirements of this project.
Chapter 3

Methodology

This thesis project has been created with the design science research methodology, which has helped structuring the work throughout the way. An agile prototyping methodology has been used for the design and development of the prototype. This chapter describes the general implementation, methodology, research, design and development of the motivational tool on Android platform.

3.1 Research method

Design science research has been chosen for this thesis project as it was found that it suits well for our project. This research is defined as an innovative design which involves creating an innovative artifact to solve a real-world problem [21, p. 9]. Design science research can be conducted in a number of ways, but for this project, we have chosen to use Alan Henver’s guidelines which provides "an understanding of how to conduct, evaluate, and present design science research" [21, p. 12].

3.2 Guidelines

The following design science framework written by Alan Henver [21] has been used. These guidelines are used to describe the research process for this project.

1. Design as an artifact: research must provide a viable artifact.

   • The final outcome of this thesis project is an Android application that is aimed to help patients be more motivated to increase their physical activity levels through quantification.
2. **Problem relevance:** develop solutions to important and relevant business problems.

   - Cancer patients are susceptible to high levels of inactivity, which can be highly dangerous and results in long durations of hospitalisation, which are costly in Sweden.

3. **Design evaluation:** the artifact must be demonstrated by good evaluation methods.

   - The design has been continuously evaluated by patients, doctors and physiotherapists who are the potential users of this software using observations, interviews and usability testing. Henver et al’s design science evaluation framework has been used to evaluate the resulting application.

4. **Research contributions:** effective design-science research must provide clear and verifiable contributions in the areas of the designed artifact.

   - The contribution will be a prototype application with a minimal interface and interaction that shows patients their physical activity levels. The resulting prototype is aimed to be used for a scientific study that will be conducted to evaluate the effect of quantifying patients’ activity levels on their quality of life and how it can reduce the hospitalisation period.

5. **Research rigour:** research relies upon the application of rigorous methods in both the construction and evaluation of the artifact.

   - Similar applications already available in the market have been researched to learn and build on their work. The prototype has been created based on iterative testing with patients, interviews and observations.

6. **Design as a search process:** utilise available means to reach desired ends while satisfying laws in the problem environment.

   - An agile prototyping pattern has been used while developing the software.

7. **Communication of research:** Research must be presented efficiently both to technology and management oriented audiences
• In addition to the application’s resulting design, this thesis is used to describe the research to both technology-oriented and management-oriented audiences.

### 3.3 Evaluation

Evaluation is a crucial part of the research process [21]. Evaluating a software can be performed in various different ways, such as usability testing, security testing, performance testing and more [25]. But since this thesis was more involved in the design and development of the front-end part of the software, usability testing and interviews with patients were performed throughout the project. In the end of the development, the application was tested (as discussed in Chapter 10) for one day with six patients to evaluate the application’s potential, the application’s usability and the patients’ acceptance and impression of the system.

Henver et al’s design science framework suggests several evaluation methods that can be used to evaluate a design artifact [21]. For this project, the following methods listed in table 3.1 were used to evaluate the artifact developed (discussed in Section 10).

<table>
<thead>
<tr>
<th>Experimental</th>
<th>Study the artifact in a controlled environment to assess its qualities (such as usability).</th>
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<tbody>
<tr>
<td>Controlled Experiment</td>
<td>Study the artifact in a controlled environment to assess its qualities (such as usability).</td>
</tr>
<tr>
<td>Simulation</td>
<td>The use of artificial data to execute the artifact without the need for having real data.</td>
</tr>
<tr>
<td>Testing</td>
<td>Examine the functionality of the application to find failures and defects.</td>
</tr>
<tr>
<td>Functional (Black Box) Testing</td>
<td>Examine the functionality of the application to find failures and defects.</td>
</tr>
<tr>
<td>Descriptive</td>
<td>Create a convincing argument for the utility of the artifact based on the relevant research.</td>
</tr>
<tr>
<td>Informed Argument</td>
<td>Create a convincing argument for the utility of the artifact based on the relevant research.</td>
</tr>
</tbody>
</table>
3.4 Data Acquisition

This project was mainly based on collecting qualitative data from hospital staff and patients.

- **Patients**

  Patients being treated at the haematology clinic at Karolinska University Hospital for cancer were selected to participate in interviews, observations and usability testing. Getting constant qualitative feedback from them during the project was highly beneficial as they directly match the targeted user group who is expected to be using the resulting motivational tool.

- **Hospital Staff**

  - **Martin Jädersten** is medical doctor who works 50% as a haematologist at Karolinska University Hospital. He has helped us throughout the project by giving us his feedback about the system and how to build a motivational software that can be implemented in the clinic.

  - **Nina Nissander** is a physiotherapist who works at the haematology clinic. She has also helped us build the product by getting her qualitative feedback after every design iteration. In addition, she helped us in finding patients who are capable of being interviewed and participate in the usability testing.

3.5 Design and development methodology

In contrast to the waterfall model which follows a linear sequential manner for software development, the software development followed for the development of this project was performed in an iterative agile manner. This methodology was chosen to ensure usability and ease of use.

There were many issues that were taken into consideration while designing the interface, as the product was being developed for a certain group of patients who were not be expected to make an effort whilst using the tool.

The core workflow of the design and development pattern followed in this project is represented in Figure 3-1. The pattern followed is inspired by the core workflow of the usability design discipline explained in an article that attempts to bridge the gaps
between software development and Human-Computer Interaction (HCI) [18, p. 125]. The reason behind choosing this discipline was to increase usability and make sure that users, which in our case are patients fully fathom and grasp the user interface of the application without squinting one eye.

In order to accommodate for the needs of the users and know more about their needs, user engagement was incorporated throughout the project. The prototyping process began with designing a mockup of the application. Usability testing was then performed on the first iteration to evaluate the application’s usability. After getting qualitative feedback from patients, a second iteration was designed and so on. The digital mock-ups were done in four iterations. We used several prototyping tools such as Adobe Illustrator\(^1\), Balsamiq Mockups\(^2\), InVision\(^3\) and Apple Keynote\(^4\) to design the mockups and make them interactive. Each iteration was followed by usability testing or interviews with patients to evaluate the design and brainstorm concepts that were criticised in the evaluation as represented in Figure 3-1.

The transition from digital design mockups to implementation occurred when the feedback from patients assured that the digital design is good enough. The two implementation iterations are discussed in Chapter 8.

\(^1\)Adobe Illustrator - www.adobe.com/se/products/illustrator.html
\(^2\)Balsamiq Mockups - https://balsamiq.com/products/mockups/
\(^3\)InVision - www.invisionapp.com/
Figure 3-1: Workflow of the Usability Design and Software Development followed in this project
Part II

Literature Review and Background Study
Chapter 4

Literature Review

This chapter describes topics that are relevant to the knowledge base of this project. It was important to get a better understanding of the environment in which this application will be implemented in. As a result, this chapter starts by describing chemotherapy, its side effects and then discusses the positive effects of physical activity for cancer patients. This is then followed by a brief overview of the current motivational tools used to increase patients’ physical activity levels. The chapter then ends with a discussion of how physical activity recognition can be performed.

4.1 Chemotherapy

This section aims to give a brief description of chemotherapy, its goals and the side effects accompanied with this treatment. As previously mentioned in Chapter 1, cancer treatment including chemotherapy and stem cell transplantation can have a significant negative impact on the patient’s quality of life due to numerous reasons. The effects occur before, during and after the treatment. Chemotherapy is defined as the use of chemicals for the destruction of cancer cells, preventing them from dividing and growing rapidly [40, p. 1]. What makes this type of treatment different from other treatments is that it is usually used as a systematic treatment, meaning that the drugs go through the whole body to reach the location of cancer cells. The problem with these drugs that destroy cancer cells is that they cannot differentiate between normal tissues (that are reproducing to replace worn-out normal cells) and cancer cells. Which as a result could damage and destroy normal cells in the process as a side effect [40, p. 3].
4.1.1 Goals of Chemotherapy

The three goals of a chemotherapy treatment are:

- **Cure**: the main goal of using chemotherapy treatment is to cure cancer in a way so that cancer cells get utterly destroyed without returning back. Nevertheless, most doctors argue that chemotherapy should be described as a treatment with a curative intent, instead of being a treatment that cures due to the lack of guarantees that ensure the effectiveness of this treatment for fully "curing" cancer [40, p. 4].

- **Control**: in some situations, being cured from cancer and destroying all cancer cells from the body might not be possible, and thus the goal of chemotherapy would be to control the disease; stop cancer cells from growing and proliferating [40, p. 4].

- **Palliation**: this term refers to reducing or easing cancer symptoms. This goal aims to enhance the patient’s quality of life without having the capability of treating the disease [7].

4.1.2 Common Side Effects of Chemotherapy

The side effects resulting from chemotherapy can vary from one patient to the other, as some might have a few or no side effects, while others might experience a few. Some of the common side effects are described below.

- **Fatigue**

  One of the most frequent and common side effects of chemotherapy affecting up to 70% of cancer patients is fatigue and tiredness. This symptom occurs when the body is trying to repair its damaged cells. Since chemotherapy does not differentiate between cancer cells and healthy cells, healthy cells get destroyed during the treatment resulting in tiredness [14]. On the other hand, aerobic exercise can significantly reduce fatigue in cancer patients undergoing chemotherapy, more details about the importance of exercise for cancer patients is discussed in Section 4.2. It is note worthy to mention that this symptom can be caused by several other factors other than chemotherapy such as the cancer itself, emotions, pain, lack of sleep, medications and lack of physical activity that all contribute to this side effect [40].
• **Quality of Life**

According to World Health Organisation, *Quality of Life (QoL)* is defined as the assessment of the general well-being of an individual based on an evaluation of the positive and negative parts of life [48]. Cancer greatly influences cancer patients’ QoL [22] and increases the risk of developing depression. Mixed emotions of fear, anxiety and depression can overwhelm patients before, during and after chemotherapy [33].

• **Neutropenia**

Neutropenia is defined as the presence of a low number of white blood cells which could result from receiving chemotherapy treatment. White blood cells form a vital part of our immune system, thus having a low number of these cells increases the susceptibility to infections [33].

• **Loss of Muscle Mass and weight**

One cause of weight and muscle mass loss is the cancer itself. The tumour mass craves more energy which forces the body to be in a catabolic state, a state in which the body consumes more than its nutritional reserves, resulting in cachexia (loss of weight, weakness and fatigue). Moreover, chemotherapy affects the gastrointestinal system which leads to various symptoms such as nausea, vomiting, diarrhoea and ineffective digestion, which all result in muscle and weight loss. In addition, fatigue reduces patients’ ability to exercise; hence, patients are more likely to be inactive and immobilised contributing to muscle loss [40].

### 4.2 Effects of physical activity on cancer patients

Physical activity is highly significant and beneficial for our systems, as it has numerous benefits such as strengthening our immune systems [50], reducing the risk for cardiovascular diseases and some types of cancers and improving our mental health and mood [16]. As a result, recent research has been investigating the effect of exercise for patients with severe diseases such as cancer.

In an interview conducted with a haematologist who currently works in the haematology department in Karolinska Hospital in 2015, doctor Martin Jädersten emphasised about the importance of physical activity during the treatment time at the
hospital. He stated that physical activity can have a great impact on a patient’s health and well being, as it decreases the risk of infection, reduces pressure ulcers and thrombosis (clotting of the blood in a part of the circulatory system), preserves muscle mass and improves the general well being.

According to a number of studies, it has been found that physical activity during cancer treatment has no harmful effect at all if the exercise was performed in moderation. In fact, a research shows that cancer patients who exercised on a regular basis were less fatigue, which is one of the primary side effects of cancer treatment [13]. This is just one of the many advantages that physical activity brings during cancer treatment. Another study found a significant benefit from exercise interventions on patients, stating that patients who received training during and after their treatment have shown a compelling increase in their Quality of Life which increases their physical performance [50]. In addition, since immobilisation and chemotherapy among other factors affect the patients’ muscle mass, physical activity before, during and after treatment can help maintain and increase muscle mass [43].

A significant study that assessed the effect of aerobic exercise on the physical performance of patients after high-dose chemotherapy reveals that patients who were given training during their hospitalisation period had 27% greater physical performance than those who were not given any training at their discharge [13].

Patients are highly susceptible to being inactive and immobilised during their treatment due to a number of factors. High levels of inactivity can be detrimental as it decreases the muscle strength by 5% per day [37], accelerates bone loss, increases the risk for thrombosis and increases the risk of pressure ulcers by 17% [13].

With all these studies that confirm the importance and safety of physical activity during treatment, we can ask the question: Why aren’t all patients well-informed about the importance of exercise? And how come inactivity is still an issue among hospitalised cancer patients?

4.3 Motivational Tools that increase Physical Activity

Motivating cancer patients to exercise and move can be an intricate issue for physiotherapists, doctors and even patients’ relatives. With the emerging studies that confirm the positive impact that physical activity has on cancer patients [50], moti-
vating patients to exercise became a high priority for clinics.

In the interview that was mentioned in Section 4.2, Dr. Martin Jädersten explained the challenges that doctors and physiotherapists face when they try to motivate patients to move more and do more exercises. He also discussed the lack of sufficient information about the patient’s physical activity levels which makes it difficult to evaluate or measure how much each patient moves. The physiotherapist who also works at Karolinska Hospital stated in a different interview: "As a physiotherapist, I cannot measure if patients perform the exercises and activities that I tell them to do." This clearly portrays the gap that exists between patients and staff.

The current traditional approach of motivating cancer patients to exercise and follow exercise programs is done by physiotherapists. This approach of motivation relies heavily on advice-giving and convincing that results in patient resistance [38].

This challenge has triggered clinics and researchers to try to find a successful way of motivating patients to increase their physical activity. As a result, many studies have been conducted to find the best way of motivating patients to move and exercise.

### 4.3.1 Pedometers

A pedometer is a digital device that keeps track of the number of steps taken by a person. This device measures physical activity using a combination of a sensor and software to track the number of steps made [39, p. 2]. With a 5% error margin [46], pedometers are considered reasonably accurate for measuring physical activity. These step counting devices have been becoming increasingly popular as a measuring device and a motivational tool.

The reason that explains why pedometers can be an effective motivational tool that motivates people to move is because these devices can continuously collect the current activity being performed, give instant feedback on the person’s activity levels (how far a person is from achieving her / his activity goal), and be a reminder to stay active [39, p. 5]. Moreover, with the addition of a software, pedometers can keep record of previous achievements which may be a motivational factor triggering a cancer patient to achieve a higher level of fitness [35].

In a systematic review that attempted to evaluate the association of pedometer use with an increased physical activity, it was found that these small insignificant devices have tremendously increased the physical activity of participants by an average of 2491 steps per day [3]. This study revealed that the main predictor for the observed
increase in the physical activity of patients was having a daily goal that motivated participants to achieve it (10000 steps per day). The results of this study are not surprising, as when people get their physical activity levels quantified, they will be able to see much they have achieved, the fluctuations in their progress and how far they are from reaching their goals. This helps people know themselves better and increases their motivation to be fit and accomplish their daily fitness goals with an element of fun.

### 4.3.2 Motivational Interviewing

The traditional approach of motivating patients to comply with an exercise program is done through direct persuasion and giving guidance and advice; nevertheless, the problem that accompanies this approach is patient resistance that often involves ignoring and interrupting the advisor or physiotherapist [38, p. 166]. This issue has resulted in the development of an alternative method of approach called *Motivational Interviewing*. Motivational interviewing is defined as a "directive, client-centered counselling style for eliciting behaviour change by helping clients to explore and resolve ambivalence" [20]. This approach is more described as collaborative instead of being authoritative, making it more successful than the traditional approach.

It is not uncommon for patients to neglect what they are advised to do by the doctors or physiotherapists. Despite knowing the significance of physical activity for their health, many patients tend to continue their treatment without showing any compliance. Motivational Interviewing aims to tackle the patients’ lack of compliance in a different way that has shown a great success in numerous studies [38].

In a journal article that was written about motivating patients to move (2005), Nancy Huang [31] argues that motivating patients to increase their physical activity is achievable using an intervention that adopts the 5A’s Motivational Interviewing approach during the consultation. This framework demonstrated in Figure 4-1 starts by **Asking** patients about their current behaviour to identify the need for increasing physical activity. It is followed by **Assessing** patients’ current activity levels using a tool such as a simple form that asks the patient about her or his activities. This part of the motivational interviewing that involves evaluating the performance of patients can be radically enhanced if there was a tool that could accurately measure how active patients are and how well are they doing. In order to increase the motivation for change, this framework’s third stage is **Advising** patients which is done by linking the
importance of physical activity on the patient’s life. This is done by giving feedback about the patient’s activity levels at that time. From here, Assisting comes next which involves suggesting additional resources and options that could help patients achieve their physical activity goals. The last stage is Arranging a follow-up that would keep that patient motivated[5, p. 2].

![5A's Motivational Interviewing approach](image)

**Figure 4-1: 5A's Motivational Interviewing approach**

### 4.4 Physical Activity Recognition

According to the *World Health Organisation*, physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure" [34]. During a typical day, we perform a variety of activities. Whether it’s walking, running, sleeping, eating or cycling, activities require energy for them to be carried out [2]. Activities can be classified in a number of ways including energy expenditure, frequency, time and intensity level.

Activity recognition is used to identify the action being performed by a person or an object using observations. In recent years, a great amount of research has been conducted to find new ways of performing activity recognition. This type of recognition can be utilised in a variety of places and scenarios. More than ever, activity recognition has gained high importance in the medical industry, specially for elderly patients [2]. More over, preventive healthcare, which is the prevention of non-communicable disease is described as a vital application domain for human activity recognition [16].

Identifying another person’s activity can be an easy task for humans to perform; on the other hand, it can be quite intricate for computers to do the same thing in an automated way. Automatic recognition of physical activities aims to identify activities
that are being performed by humans [2]. There are a number of techniques that have been studied to perform automated physical activity recognition.

4.4.1 Methods and Techniques

One of the most common techniques used for activity recognition is cameras. The main advantage of using this technique is that users are not required to wear any device; nevertheless, this technique can be problematic due to a number of reasons. One problem is that this technique is dependent on light and ambient conditions. Another drawback is that there are some privacy concerns, as people might not feel comfortable being recorded during their day. Moreover, cameras require physical installation which could be expensive and infeasible in some situations.

In addition to cameras, a widely accepted technique that is also used for activity recognition is wearable electronics such as watches or bracelets that encompass technology capable of retrieving information that can be utilised to identify the person’s physical activities.

Here are some of the sensors that are commonly used in activity recognition:

- **Accelerometer**
  
  An accelerometer is a type of measuring sensor that measures the proper acceleration. This device emits an electrical signal which is in some way proportional to the speed change (acceleration) sensor is subjected to. Accelerometers are the most used sensors for activity recognition due to their reasonable consumption of power, small size, accuracy in identifying body movements and reasonable price [29]. 3-axis accelerometer (Figure 4-2) is the most common type of accelerometers nowadays that returns an approximate value of acceleration along 3 axes (x, y and z). These devices are used for motion detection, body-position and posture sensing [17].

- **Gyroscopes**
  
  Although they are less used than accelerometers, gyroscopes can be useful for classifying human activities as they provide information about the angular velocity which cannot be provided by accelerometers [2].

- **GPS**
  
  GPS (Global Positioning System) devices are not only being used for navigational purposes, but also as sensors that measure human activity based on
wider scale (such as a city or regional scale). Although these sensors are accurate and useful to get the position of the user outdoors, they do not work well indoors [45].

All in all, human activity recognition can be carried out using a number of technologies such as cameras and sensors. Although it can be a challenge to recognise the activity being performed by another human being using a computer, the world has seen a continuous progress and improvement in this field. Different activities can be identified using sensors, but their accuracy significantly depends on the location of the sensor, number of sensors worn and type of information retrieved. At the moment, accelerometers are considered to be the most used sensors for their motion detection capabilities.
Chapter 5

Mobile Health Solutions

This chapter describes some of the tools that have been developed with a similar aim to the one taken in this project, which involves helping patients get better and reducing costs for hospitals and patients. Numerous mobile health solutions have been on the rise in the past years, specially with the prevalence of light-weight inexpensive wearable sensors [26]. Mobile health solutions can significantly help the movement of information between patients and health care providers and give a better overview of how the patient is feeling. These solutions also actively increase patient participation, giving an opportunity for patients to feel more involved in their own treatment.

5.1 Mayo Clinic myCare

Mayo Clinic myCare program uses an iPad tablet to supply patients with comprehensive information about their treatment [9]. This program is created to guide and support recovery. The main aim of this application is to help cardiac surgery patients and their relatives engage in the pre and post-surgery process. It gives detailed information about the patient’s expected plan of stay and plan of day. Moreover, it provides comprehensive educational content, giving patients and their relatives a better overview of what they need to know before and after surgery to help them recover and manage their pain more efficiently. Also, this product has a "To Do" list that gives the patient a set of tasks that she or he has to do, such as a movement assessment or breathing exercises all of which are set to help patients feel better and more engaged. Pain self-assessment gives patients the capability to enter how they are feeling using a Visual Analog Scale (VAS). This helps patients manage their pain and
keep it under control to do what is required to help them recover faster [8]. Patients can still use the application even when they have been discharged from the hospital.

Figure 5-1: A screenshot of Mayo myCare program’s patient view

The data retrieved by the tablet get sent to a server in the cloud to let nurses and physicians caring for the patients access patients’ information. Figure 5-2 shows a population patient dashboard which shows all patients involved in the program. The care providers can also view a dashboard for a specific patient as well [9].

After developing the application, Mayo Clinic wanted to evaluate the results and benefits achieved from using the application. In 2012, a total of 134 patients participated in the study and the results suggested that this program can help reduce hospitalisation time, decrease cost of care and enhance patients’ ability to be more independent after being discharged from the hospital [9]. A year later, Mayo Clinic has decided to utilise FitBit technology with their MyCare app program to track the mobility of the patient and show the results on the tablet, which is similar to what
is being developed in this thesis project. In 2013, An overall of 149 patients were given iPads and FitBits to use the MyCare program, and it was astounding that it has received around 98% engagement. It was also found that using the app was not relevant to the patient’s age, meaning that young and adults enjoyed using the app equally [49].
5.2 ZephyrLIFE Hospital - Wearable Patient Monitoring System

ZephyrLIFE Hospital is a wearable patient monitoring system for patients staying at the hospital. This system makes use of a wireless BioPatch, a patch worn on the patient’s chest that send signals to ZephyrLIFE monitoring system using a mesh radio. The system measures vital signals including heart rate, respiration, blood pressure, activity minutes, posture, body temperature and more. As shown in Figure 5-3, this system combines vital signals sent using a mesh radio and secure wireless communications to provide patient monitoring through a central monitoring system. This system is designed to facilitate remote patient monitoring in an easy and simple way. First, the BioPatch applied on patients retrieves vital signals that get transmitted to ZephyrLife Central Monitoring Station using a secure connection initiated by a Mesh Radio. The hospital staff then get access to the data using the ZephyrLife Central Monitoring Station. This monitoring station is made to provide a secure terminal in which hospital staff can monitor patients’ health at all times.

Despite the efficiency in centralising patients’ data in one system, the wireless device (BioPatch) applied on patients have a battery life of only 24 hours. As a result, this device requires frequent charging, which causes some troublesome for patients and staff as these devices have to be taken away and put on charge, and then put back on patients once they run out of battery. On the other hand, the device is made to be easily disinfected by normal cleaning agents, and this feature is highly important for devices used in a hospital environment [51].

5.3 Welfare Denmark’s Virtual Rehabilitation

Welfare Denmark’s Virtual Rehabilitation is the world’s most advanced virtual rehabilitation system in the health care industry. This system can be described as a tool that assists physiotherapists and patients by providing efficient rehabilitation to patients right in their homes. This training-system is based on a combination of a Microsoft Kinect-sensor that detects the body’s movements and training programs set by physiotherapists. The training programs can be accessed from the patient’s home. The patient accesses the training program that was set by the physiotherapists, resulting in an easy and manageable way for therapist to have full control.
While the training is carried out, all the data retrieved through the system is sent to the physiotherapist to know if patients have completed their training programs and how well did they perform. The allocated physiotherapist can then take subsequent action when she or he receives the results from the exercises. Physiotherapists can adjust the patient’s program online and be available to the patient the next time they turn on the system. This technique motivates patients to follow the training programs as they know that someone is constantly checking their results [47].

5.4 Chapter Conclusion

We have used the review of applications developed for patients as an inspiration to how to design our application. All three applications reviewed are in the same domain as our application, with an aim of helping patients get better and healthier. Although all applications share the same target user group, they present far more detailed information than entailed in our application. Nevertheless, it was useful to get inspiration from their designs and their motivational methods.
Chapter 6

Wearable Devices

IoT has been thriving rapidly in the past years due to the availability of low-cost sensors that are available in the market with various kinds of functionality [42, p. 219]. Numerous devices and solutions currently available in the market include sensors that are able to retrieve a vast amount of data that help quantify users. Such devices can retrieve movements using an accelerometer, heart rate using an ECG, temperature, moisture and location via a GPS and many more measurements.

6.1 Device Requirements

While studying the numerous wearable devices that are available in the market, several factors were taken into consideration. The chosen wearable solution had to comply with the following requirements for this project as the target users were patients. Some of these requirements were added as a recommendation from the hospital staff at Karolinska Hospital.

- The wearable solution should be based on an open platform that allows open access to the data retrieved by the sensor; hence an open SDK is needed.
- The wearable solution must encompass an accelerometer and/or gyroscope to capture the body’s movement.
- The wearable solution should provide a wearable solution that can be easily worn by patients without any discomfort.
- The wearable solution should be water resistant to make it possible for the device to move between patients without spreading any contamination, thus it
is highly vital that the device can be disinfected using a sanitiser in a fast, safe and simple way. The device should be able to be worn while showering.

- The wearable solution should not interfere with taking care of patients. The placement of the device should be adequate without causing any sort of interference to normal practices performed in the hospital.

- The wearable solution should be fully automatic and work without any user interaction. Patients are not expected to be interacting with the sensor; therefore the sensor should be able to work and connect to the tablet without any human interaction.

- The wearable solution should have a long battery life. A minimum battery life of five days is adequate for this research project, as having to charge the device frequently might interfere with the patient’s comfort.

- The wearable solution must be accompanied with low-energy Bluetooth 4.0 technology to reduce battery consumption.

### 6.2 Devices

This section examines the wearable devices currently available in the market based on several factors including the sensors embedded in the device, performance, battery life, availability, water-resistance, compatible operating systems, placement and connectivity. This analysis was conducted to find an adequate wearable device that can be used for this project.

**Fitbit Surge**

Fitbit Surge, released in the last quarter of 2014, is one of the latest editions to Fitbit’s wearable fitness devices. What makes it different from previous Fitbit editions is that this device encompasses GPS tracking, in addition to continuous heart rate monitoring [24, p. 104]. What makes this device suitable for this project is that it has a built-in accelerometer and a long lasting battery life that lasts more than 7 days, which is quite impressive in comparison to other wearable fitness devices. Nevertheless, the problem with this wearable device is that raw data collected via the built-in accelerometer cannot be retrieved as the API merely allows access to Fitbit user’s
data and not raw accelerometer data making it impossible to access raw data without being processed through Fitbit’s application. In addition, the surge is accompanied with a screen that allows user interaction, thus this is another reason that makes it inadequate for this project as one of the requirements for the chosen device is that it should be used without any user interaction.

Sensors: 3D accelerometer, vibration motor, GPS, gyroscope, altimeter, ambient light sensor, compass and heart-rate sensor
OS Compatibility: Android and iOS
Connectivity: Bluetooth 4.0
Battery Life: 7+ days
Raw Access: not accessible
Disinfection method: can be cleaned with a soapless cleanser

**Fitbit Charge HR**

Fitbit Charge Heart Rate is very similar to Surge except that it has a smaller OLED screen. It was also released with the Surge in the end of 2014. Fitbit Charge HR lasts for a shorter period than its sister device (Surge) with only 5 days of battery life. Despite being a good choice for this project for the data that it can retrieve, Fitbit Charge HR does not allow developers to access unprocessed raw data retrieved through the built-in sensors in the device, hence it cannot be used for this project [2].

Sensors: 3D accelerometer, altimeter, vibration motor and optical heart-rate sensor
OS Compatibility: Android and iOS
Connectivity: Bluetooth 4.0
Battery Life: 5 days
Raw Access: not accessible
Disinfection method: can be cleaned with a soapless cleanser

**Microsoft Band**

Although Microsoft band is equipped with 10 different sensors that can track the body’s movement, heart rate, sleep quality and UV exposure, the wearable device that’s compatible with Android, iOS, Windows Phone, Mac OS X and Windows has a battery life of only 48 hours [2]. The short battery life makes this device unsuitable
for a hospital setting, as the aim of this project is to use a sensor that has a long lasting battery life to reduce the frequency of removing the device off the patient for charging.

Sensors: 3D accelerometer, thermometer, ambient light, UV sensor, microphone and optical heart-rate sensor
OS Compatibility: Android, iOS, Mac OSX, Windows and Windows Phone
Connectivity: USB and Bluetooth 4.0
Battery Life: 48 hours
Raw Access: not accessible
Disinfection method: instructions on Microsoft’s website state that the device can be cleaned using a screen wipe, soft cloth, and a cotton swab after being dipped in water.

**Olive**

Olive is a wearable device that aims to help people manage and reduce their stress levels. This device uses data retrieved from its built-in sensors to learn the person’s lifestyle pattern, and thus making the experience more personalised [28]. Despite having a minimum interface that makes its industrial design great for our solution, Olive does not have an open API that developers can use to build their products. In addition, the first estimated shipping date for delivery is in November 2015 which is after the duration of this project.

Sensors: 3D accelerometer, optical pulse sensor, ambient light sensor, touch surface and skin conductance sensor
OS Compatibility: iOS and Android
Connectivity: Bluetooth 4.0
Battery Life: unknown
Raw Access: not accessible
Disinfection method: can be cleaned using a soft cloth dipped in water.

**Nike+ FuelBand SE**

Nike+ FuelBand is a dominant market product [19] that is considered to be an activity tracker worn on the wrist. This device measures the number of steps made per day using a 3D accelerometer. What makes this device special and unique in comparison
to its competitors is that it has a concept of "Fuels" which represents a score that keeps track of how much each user moves. The more you move, the more fuel points you earn. The main aim of using a wearable device in our project is to utilise its sensors, and although an accelerometer would be great for activity recognition, Nike+ Fuelband’s API allows developers to handle activity services (such as retrieving list of activities, retrieving GPS data and adding activities) but without the ability to access the raw data collected by the built-in 3D accelerometer [30].

Sensors: 3D accelerometer and light sensor
OS Compatibility: Android, iOS
Connectivity: USB and Bluetooth 4.0
Battery Life: up to 4 days
Raw Access: not accessible
Disinfection method: can be disinfected by rubbing the device with a cloth dipped in alcohol.

**Pebble**

Pebble smart watch is a waterproof cheap smart watch that has a long-lasting battery that can last up to 7 days. Ranked as one of the best watches for the money, Pebble connects to an iPhone or Android via Bluetooth. In addition, this watch encompasses sensors that recognise one’s activities. What makes this activity tracker better than others for our project is that it provides open access to the collected data, which means that all measurements retrieved by the Pebble’s accelerometer can be accessed. This makes this device suit well for this project.

Sensors: 3D accelerometer, compass and light sensor
OS Compatibility: Android, iOS
Connectivity: Bluetooth 4.0
Battery Life: up to 7 days
Raw Access: open platform
Disinfection method: can be disinfected with a cleaning cloth moistened with water, alcohol or a mild detergent.
6.3 Comparison Summary Table

In Table B, a comparison summary of the analysed wearable solutions is shown to briefly summarise the features and capabilities of each device. The comparison is based on a number of features including the placement of the wearable device, sensors embedded in the device, battery life, charging time, memory, user interaction, disinfection method, water-resistance, compatibility with Android and if the device allows developers to access to the raw data.

6.3.1 Conclusion

Although the emerging use of wearable technology and the rise of an age of smart watches have resulted in numerous devices to be available in the market; however, most of these devices do not allow developers to access the raw data retrieved by the built-in sensors encompassed by the device, which was one of the main requirements whilst choosing a device.

After performing a comprehensive comparison between a vast number of wearable solutions available in the market, the Pebble watch has been chosen to be used for this project due to a number of reasons. In addition to having a 3D accelerometer that can retrieve measurements of the user’s movements, Pebble Watch is a lightweight device that was found to be one of the best wearable devices for this project. The detachable rubber bands attached to the watch were very useful for testing the device on patients, as the bands were removed and the device was put on the patient’s chest instead of the wrist in order to detect a broader range of activities. This device is android compatible; PebbleKit Android library was added to the project to connect the Android application to the pebble watch. Regarding its connectivity, this device is connected via Bluetooth 4.0 which is considered to be a low energy technology which reduces the battery consumption [42, p. 220]. Since the product is aimed to be applied in clinics in hospitals, thus it was of high importance for the device to have a long lasting battery to reduce the hassle of frequent charging of this device, and Pebble watch definitely wins over its competi-
tors when it comes to battery life by offering a weeklong battery life. Moreover, it was necessary to find a device that could be disinfected easily and can be worn while showering, and with water resistance up to 50 meters, Pebble watch can definitely be a great product for this purpose.

In order to test the adequacy of this device for this project, one of the team members has attached the Pebble on her chest with a medical patch for five consecutive days without showing any problems while showering, exercising, sleeping and doing normal daily activities.

Moreover, testing the device while sending accelerometer data to the tablet was highly important to evaluate if we can use this system for long periods of time. It was found that the device’s battery is capable of continuously sending data to the tablet for 5 - 6 days. The Pebble’s capacity of saving the captured data without being connected to a tablet was also evaluated as well. The Pebble is capable of saving 3 hours of data logging without a connection; otherwise, the device starts erasing the oldest measurements to make space for new ones.
Part III

Application Design and Development
Chapter 7

Application Design

This chapter introduces the challenges that have been encountered while designing the motivational tool and then discuss the design iterations.

7.1 Design challenges

This section gives a brief overview of the risks and challenges that have been faced while designing the interface and during the usability testing sessions.

User experience

As previously discussed in Section 3.5, it was highly important to focus on the usability of the motivational tool as the target users are patients who are being treated for cancer at the hospital. And thus, we had to involve patients throughout the project to ensure that they can effectively understand and interact with our application. We had to give patients an overview of their activity levels in a lucid way that would motivate them to move more without getting in the way of their treatment. Most patients being treated for cancer feel fatigue and tired, and thus this issue had to be taken into consideration while designing this system. Although user-engagement is considered to consume a great amount of time and effort; however, it was exceedingly important to work in a user-centred way.
## Iterations

The adequate number of iterations set for the design and the development of the application was not known from the start. But as we moved from one iteration to the next one, the interface’s usability increased. After four iterations of the digital design of the application, the interface was usable enough to be implemented. This is when we chose to switch from the digital design to the implementation.

## Usability testing sessions

With the help of the physiotherapist who works at the haematology clinic in Karolinska Hospital, Nina Nissander, we were able to conduct usability testing with prospective users who were chosen from the list of patients currently present in the clinic. Each individual session lasted about half an hour. During each session, patients were given a brief overview of the purpose of the application and the test session. Patients were then asked to perform a series of tasks. In addition, each session captured patients’ opinion and feedback regarding this motivational tool.

## Selection of test users

The users who were selected for the usability testing were patients getting treated for cancer at the haematology clinic in Karolinska Hospital. Since not all patients were healthy enough to be interviewed or involved in the study, the physiotherapist assisted us in finding patients who are well enough to be involved.

## Language barrier

The users who were interviewed and selected for the usability testing were all Swedish, and hence the language that was used for the application, interviews and usability testing was Swedish. Nevertheless, with the help of the accompanied doctor(s) and physiotherapist(s), this issue was handled.

### 7.2 Prototyping

This section describes the prototyping process that was followed during this project. This includes designing digital mockups of the application and testing them on users.
to get their feedback which was constructive to every iteration.

### 7.2.1 Usability Testing

Usability testing is defined as "evaluating a product or service by testing it with representative users" [44]. For a product or a service to be usable, it has to be effective, adaptable, accessible, efficient, useful without causing any frustration. Having a usable product means that the user can easily understand the product and can navigate through it without any hindrance or confusion [36, p. 4].

The main aim of the motivational tool created in this project was to motivate cancer patients to increase their physical activity by giving instant feedback of their physical activity levels. As a result, usability of the product was of high importance to ensure that patients are able to understand what the product is portraying. According to *Handbook of Usability Testing* (2011), Jeffrey Rubin and Dana Chisnell argue that the best practice for conducting an effective usability testing involves creating a solid test plan prior to the usability testing [36, p. 66]. The second stage involves recruiting participants, followed by conducting the usability testing with the participants involved. The final stage is to document the findings of the usability testing and analyse the results. The usability testing in this project has been performed in the same way suggested in the book. The first usability testing was conducted after the design of the initial concept mentioned in the introduction.

The following part discusses the internal design cycles that were performed while developing the software.

### 7.2.2 Design Iteration 1

After conducting the user study at the hospital, a first mockup was designed to visualise the patients’ activity levels. To evaluate the usability of the initial digital design of the interface, a usability testing was conducted on the 19th of February, 2015 with assistance from Dr. Johan Hedevåg and physiotherapist Nina Nissander. In this interface, shown in Section C.1 in the Appendix, users are able to track their activities using vertical bar charts. Users are also able to check their history that shows a line diagram summarising their activity levels in the previous days and enter their pain and mood levels. A concept of "Activity Points" was created for this interface to keep track of the patients’ progress in one number. This number is calculated depending
on the weight of each activity and the time spent on it. Physiotherapists are able to set goals in terms of "Activity Points" for each patient.

**Usability Testing Summary**

The purpose of the usability test was to assess the usability of the user interface, the presented information and information flow. A total of 3 patients were involved in the usability test to ensure stable results. In general, all patients found the application easy to use, clear, and straightforward; however, the test identified some problems including:

- Misinterpretation of the "How are you doing" button due to the scale image behind it.
- Misunderstanding of the icon that resembles the activity "sitting up". A patient assumed that it represents waking up instead.
- Misunderstanding the icon that resembles the activity "lying down", a patient thought that it might resemble sleeping which caused some confusion.
- It was rather difficult to understand what "earlier results" meant in the mood page, as the word earlier can be vague.
- Misunderstanding the titles due to their location below the charts / activities.
- Misunderstanding the general definition of the concept of activity points.
- Confusion about the term "Spara" which is the submit button in the mood page.

**Evaluation Tasks**

Test participants were asked to complete the following tasks:

1. Check your history.
2. Check yesterday’s daily overview.
3. Fill in how you’re feeling.
4. Compare your performance between yesterday and today.
Results

Table 7.1: Task Completion Analysis

<table>
<thead>
<tr>
<th>Patient</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Patient success rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
<td>75%</td>
</tr>
<tr>
<td>3</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
<td>50%</td>
</tr>
<tr>
<td>Success</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>avg: 75%</td>
</tr>
<tr>
<td>Task Completion Rates</td>
<td>100%</td>
<td>100%</td>
<td>33.30%</td>
<td>66.70%</td>
<td>-</td>
</tr>
</tbody>
</table>

All participants successfully completed the first two tasks (check your history and check yesterday’s daily overview). Only one of them (33.3%) was able to complete task 3 (navigate to the mood/pain page) probable due to the confusion caused by the scale behind the button. Two of the participants (66.7%) were able to complete task 4 (compare your performance between yesterday and today).

Task Ratings

1. Check your history
   All participants agreed that navigating to the history page is easy, regardless of their computer literacy.

2. Check yesterday’s daily overview
   The left navigation button was easy to find on the daily overview page, and thus caused no confusion for the patient to check yesterday’s daily overview.

3. Fill in how you’re feeling
   Only one patient was able to complete this task without any confusion. The other two patients thought that the "hur mår du?" button is a scale that can be moved up and down. Hence, instead of pressing on the button, they attempted moving this fixed button vertically, which did not result in any change.

4. Compare your performance between yesterday and today
   One of the patients did not fully fathom what activity points are, and hence took him more time to understand the difference between his performance yesterday and today.
**Recommended Changes**

The following recommendations were set to be analysed and worked upon to enhance the overall intuitiveness and ease of use of the application before conducting a second usability testing session.

- Remove the scale behind the "hur mår du?" button to make it clear that this button is clickable without confusion.
- Put the titles on top of the charts instead of the bottom part.
- Add labels for each icon explaining each activity.
- Improve the icon that represents sitting up.
- Have a better explanation for Active Points
- Add a last input timestamp for the gauge charts that show what mood or pain has been previously entered.

**7.2.3 Design Iteration 2**

The interface for this iteration was designed after performing the recommended changes of the first usability testing and can be found in Section C.2. To evaluate its usability, usability testing was conducted on the 25th of February, 2015 with assistance from Dr. Johan Hedvåg and physiotherapist Nina Nissander. To address the problem with patients having difficulties entering their pain and mood levels, we added an avatar with a button that asks the patient about their current status.

**Usability Testing Summary**

The purpose of this usability test was to assess the usability of the user interface after doing the recommended changes that were instructed in the first usability testing. A total of 3 patients were involved in the usability test to ensure stable results. The test has identified some problems including:

- Misinterpretation of the "How are you doing" button due to the figure.
- It was a bit difficult to compare between current and earlier entries in the mood / pain page.
• Confusion about the arrows that allow the user to navigate between the days in the Daily overview.

• Difficulty in understanding the line chart that shows the progress of the patient in the history view.

Evaluation Tasks

Test participants were asked to answer / complete the following tasks:

1. How many points have you gotten today?
2. Check your history.
3. How many points did you get on the week’s best day?
4. Check yesterday’s daily overview.
5. Can you compare between your performance yesterday and today?
6. Fill in how you’re feeling.
7. Can you check what activity points really mean?

Results

Table 7.2: Task Completion Analysis

<table>
<thead>
<tr>
<th>Patient</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
<th>Task 6</th>
<th>Task 7</th>
<th>PSR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>✓</td>
<td>14.3%</td>
</tr>
<tr>
<td>2</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
<td>×</td>
<td>71.4%</td>
</tr>
<tr>
<td>3</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>71.4%</td>
</tr>
<tr>
<td>Success</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>avg: 52.4%</td>
</tr>
<tr>
<td>TCR**</td>
<td>33.3%</td>
<td>66.7%</td>
<td>33.30%</td>
<td>66.70%</td>
<td>66.70%</td>
<td>33.30%</td>
<td>66.70%</td>
<td>-</td>
</tr>
</tbody>
</table>

* = Patient Success Rate ** = Task Completion Rate

Tasks 1, 3 and 6 were successfully completed by only one patient. While the rest of the were completed by two patients. This indicates that there is a significant problem here as no patient was able to successfully complete all tasks asked and no task was successfully completed by all patients.
**Task Ratings**

1. How many points have you gotten today?
   Only one participant was able to locate the number of points achieved today, this might be due to the location of the text that indicates the number of points achieved, as it’s located underneath the chart. Patients were not able to locate the text due to its location and size.

2. Check your history.
   Two patients were able to locate the history button easily. Some patients were able to understand the changes that have been occurring with their activities from the line chart. However, it might be more understandable to have a chart that shows the correlation between these activities in a better way. One patient did not understand that she was on the history page, despite having that tab highlighted.

3. How many points did you get on the week’s best day?
   Only one patient was able to locate the "week’s best day" and understand how many points have been obtained on that day. However, it might have been confusing to have the number of points achieved inside the chart, which is not the same for the daily page.

4. Check yesterday’s daily overview.
   Two out of the three patients were able to easily navigate to yesterday’s daily overview. Perhaps we could have "Previous day" and "Next day" to indicate what these arrows resemble to make it easier for users to navigate between days.

5. Can you compare between your performance yesterday and today?
   Two out of the three patients were able to easily compare their performance between today and the day before. They used the bars and the circular progress bar that represents the completed active points as a factor for comparison.

6. Fill in how you’re feeling.
   One of the patients had no idea how to fill this in. She said "I don’t know". The other two patients were eventually able to locate the button that lets you fill in your information, but it was not intuitive. One patient pressed the figure instead of the button at first. Another one pressed the bubble. It was hard
for patients to compare their current status with the previously entered mood / status. And this indicates another problem with the design.

7. Can you check what active points really mean?
   It was generally easy for patients to understand that the question mark would let them know more information about what activity points really mean. One patient clicked on the circular chart instead of the question mark. They had trouble hitting the question mark and missed it when they tried to push it.

**Recommended Changes**

The following recommendations were analysed after the second iteration.

- Change the location and increase the size of the activity points achieved today, as it was not obvious for the patients.

- Line chart in the history page should be easier to understand.

- A clear line between history and best day to show that they are separate

- Think about the consistency between the activity points chart, as the one in the daily page represents the percentage achieved in the middle, whereas the one in the history page shows the number of points achieved. Thus, these two charts should be more consistent in order to increase the intuitiveness of the application.

- Add "Next day" and "Previous day" next to the arrows that allow the user to navigate between days in the daily overview page.

- "How are you feeling" button should be changed so that it’s easy to understand to motivate patients to enter their current pain and mood levels.

- Add Hours/Minutes/Time axis on the column chart in the daily overview page to help users understand what the chart is representing.

**7.2.4 Design Iteration 3**

After following some of the recommended changes proposed in the previous usability testing, we have designed a new design for the third iteration to address the captured problems. Interviews with patients were conducted to evaluate this interface on the
5th of March, 2015 with two members of the team. The interface created in this iteration can be found in Section C.3. The interface for this session was reduced to a daily view that solely shows the patient’s progress on that specific day in that specific time without other functions that were previously included in previous tests and interviews. The reason behind this decision was to increase the simplicity of the application and reduce the interaction needed between the user and the system. Six patients were asked for their opinion about the application as a whole and the functionalities that it entails. In addition, they were also asked for their opinion about having a sensor applied on them.

**Questions**

Patients were asked the following questions in each interview:

- What do you understand from the user interface?
- What do you think of having the estimated number of days left for being discharged shown on the screen?
- Would you use this product to help you move more?
- What would motivate you to move more?
- How do you feel about having a sensor on your body to get quantified information about your physical activity?

**Summary of patient interviews**

The interviews with the patients have identified some observations including:

- Misinterpretation of the icon that resembles sitting, as it currently shows a person sitting on the side of the bed, which might be interpreted as moving upwards or sitting on the bed. Thus, this icon should be changed into something clearer.

- After showing patients three different charts (bar, stacked and pie) that represent their activity levels, it was found that the vertical bar chart was the easiest to understand. As a result, it was decided at this point to use vertical bar chart.
Some patients loved the idea of having the estimated number of days left for them to be discharged shown on the screen. However, this might cause some complications if the number was inaccurate, as it could raise the patients’ expectations and then cause some disappointment if the number was wrong.

One of the patients talked about the need for setting goals that would motivate patients to work towards achieving them, as solely quantifying their data might not be sufficient enough to motivate them.

The pebble was not a problem for any of the patients, and it was easy to disinfect while trying it on different patients.

Most patients showed interest in using these tools to help them get motivated to increase their physical activity.

7.2.5 Design Iteration 4

In previous iterations, activity points were used as a concept to motivate patients to increase their physical activity. However, in this iteration, we developed four different concepts that resemble the progress of patients in terms of points. Interviews with patients were conducted to evaluate this iteration and receive more feedback from patients about the application. Screen shots of the interface used for this iteration can be found in Section C.4.

Questions

Patients were asked the following questions in each interview:

- What is your preferred location of the sensor? Chest or on your wrist?

- Which concept is the easiest to understand and could stimulate you to increase your physical activity.

- What do you understand from the activity bar chart?

Concepts

Four concepts were tested on patients to get their feedback. The interfaces of these concepts can be found in appendix C.
• Concept 1 (Figure C-7): Activity points resembled by a gradient circular progress bar that contains the percentage of the completed goal.
Observations:
- Most patients found the percentage of activity points achieved in that day easy to understand after being informed about how the activity points concept works.
- Some patients found this concept to be clear, but rather boring in comparison the the last two concepts that make activity points more exciting.
- Patients were able to grasp that the more active you are, the more activity points you get.

• Concept 2 (Figure C-8): Activity points resembled by a circular progress bar that is divided into segments that represent different activities with different colours.
Observations:
- Most patients were able to understand this circular chart easily.
- Patients were able to recognize that the circular progress chart is segmented into separate activities.

• Concept 3 (Figure C-9): Activity points resembled by a game where the player has to go from point A to point B.
Observations:
- Patients gave a positive feedback of having a game-like concept that would motivate the patients to achieve their daily goals in a more exciting manner.
- Patients were able to understand that the more active they are, the more points they gain and thus the player will move towards the goal.

• Concept 4 (Figure C-10): Same concept as concept 3 with an opponent aimed at stimulating the patient to compete with himself / herself.
Observations:
- Two of the three patients that were interviewed loved this concept the most.
- Competing with oneself retrieved a better feedback than competing with other patients.

Summary of Concepts

Table 7.3: Concept Preference

<table>
<thead>
<tr>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
<th>Concept 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>×</td>
<td>1</td>
<td>×</td>
<td>2</td>
</tr>
</tbody>
</table>

Concept 2 was liked the most by only one patient who felt that numbers make things easier to understand the concept of activity points. On the other hand, concept 4 was well-received by the two other patients.

Nina Nissander, the physiotherapist at the haematology department gave us some feedback about the concepts:

- Concept 2 is easy to understand as it resembles the percentage of activity points achieved by each activity; however, other colours are advised to be used.

- Concept 3 might be more suitable for younger patients.

- Concept 4 might not be suitable in situations where the patient is severely sick, as having an opponent constantly defeating the patient might not be a suitable motivator for the patient.

Location of the Sensor

Table 7.4: Sensor Location Preference

<table>
<thead>
<tr>
<th></th>
<th>Wrist-band sensor</th>
<th>Chest sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>×</td>
<td>✔</td>
</tr>
<tr>
<td>Patient 2</td>
<td>✔</td>
<td>×</td>
</tr>
<tr>
<td>Patient 3</td>
<td>✔</td>
<td>×</td>
</tr>
</tbody>
</table>

Note: One of the patients had skin allergy, which could be a common problem with the patients who are overwhelmed the devices attached to them.
Conclusion

Concept 4 was the most well-received concept among all concepts shown to users, but due to limited time, we were not able to implement this concept. A future version of the application could allow the user to select the most preferred way of representing activity points. Regarding the location of the sensor, the most optimum solution for this issue is to give patients the freedom to choose the location that they prefer without interfering with the effectiveness of the algorithm that detects patients’ physical activities. On the other hand, for this project, we have chosen to put the sensor on the patient’s chest.
Chapter 8

Application Implementation

This chapter introduces the challenges that have been encountered while implementing the motivational tool. In addition, the design, functional and non-functional requirements of the application are then listed. Finally, the application’s view models are presented.

8.1 Implementation challenges and risks

During the implementation of any software, there are many challenges and risks that should be considered in order to identify any shortcomings of the resulted application. This section addresses the challenges and risks that were taken into consideration in this project.

Technical expertise

Due to a limited experience in developing Android applications, technical challenges existed in the implementation phase. The risk here was that a considerable amount of time could be spent on getting accustomed to Android development and finding Android libraries needed for this project.

Requirements change

Since agile methodology was chosen for the application design and development, a change in the requirements and the design of the application is always expected at any stage. As a result, we have conducted four design iterations prior to the imple-
mentation iteration that constantly involved prospective users to avoid any structural changes of the application.

8.2 Requirements

The requirements were specified based on user studies, interviews, observations and usability testing. Due to the agile methodology chosen for this project, the requirements were continuously adjusted throughout the project.

The requirements listed below were eventually evaluated using black-box testing as described in Section 3.3. Each requirement specified was manually tested for its completion in the final developed application.

8.2.1 Design requirements

Table 8.1 lists the design requirements entailed in the application, in addition to their priorities and status of completion.

Table 8.1: Design Requirements

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Priority</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>ICONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1.1</td>
<td>The icons should effectively represent each activity.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>D1.2</td>
<td>The icons should be big enough to be seen from a distance.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>D1.3</td>
<td>The icons should be accompanied with labels that represent each activity (active, inactive, sitting and standing).</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>D2</td>
<td>ACTIVITY BAR CHART</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2.1</td>
<td>The chart should show the time spent on each activity with bars.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>D2.2</td>
<td>The chart should have labels on both axes.</td>
<td>High</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Continued on next page
Table 8.1 – *Continued from previous page*

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Priority</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2.3</td>
<td>The chart should show the independent variable which is time on the y-axis and the dependent variable which is the activity on the x-axis.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>D2.4</td>
<td>The chart should show the weight of each activity next to the activity’s label (active x6), which means that for every active minute, the patient gains 6 activity points.</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>D2.5</td>
<td>Each activity bar should have a value that states the exact amount of time spent on that activity.</td>
<td>Low</td>
<td>Yes</td>
</tr>
<tr>
<td>D2.6</td>
<td>Each activity bar should be represented with a different colour that resembles that activity.</td>
<td>Low</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**D3 Activity Points**

| D3.1 | Activity points should be represented with a circular pie chart by showing the percentage of the patient’s progress based on a goal set by the physiotherapist.                                           | High     | Yes       |
| D3.2 | There should be a label inside the pie chart that indicates the percentage of the patient’s progress.                                                                                                       | High     | Yes       |
| D3.3 | The patient’s goal and current activity points should be shown to the user in exact numbers.                                                                                                                 | Medium   | Yes       |
| D3.4 | The current status of the patient / last activity recognised should be presented underneath the pie chart.                                                                                                   | Low      | Yes       |
| D3.5 | The pie chart should show progress even after the completion of the patient’s daily goal.                                                                                                                  | Low      | No        |

**8.2.2 Functional requirements**

Table 8.2 lists the functional requirements entailed in the application, in addition to their priorities and status of completion. A functional requirement is defined as a function that a system or a part of a system should do.
<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Priority</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>The application should retrieve measurements from a connected Pebble that is applied on patients and process these measurements using a machine learning algorithm to recognise the activity.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F2</td>
<td>The time spent on each activity per day should be shown using a vertical bar chart.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F3</td>
<td>Activity points should be automatically calculated based on the amount of time spent on each activity and the weight of the activity.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F4</td>
<td>The bar chart and activity points pie chart should always be visible to the patient and show the current activity levels.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F5</td>
<td>The training sets used to train the machine learning algorithm should be stored on the tablet in order to be used for activity recognition.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F6</td>
<td>The chart should be adaptable based on the chart’s maximum y value so that the maximum y-axis set on the chart increases relatively.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F7</td>
<td>The icons should be automatically generated from the training sets that are locally saved on the tablet.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>F8</td>
<td>The activities on the x-axis must be sorted in ascending order from left to right based on their weights.</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>F9</td>
<td>There should be a hidden gesture that allows the physiotherapist or doctor to set a daily goal that the patient should achieve.</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>F10</td>
<td>A local database should be implemented to store the measurements recorded from patients.</td>
<td>Medium</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Patients should be able to enter their pain and mood levels.

### 8.2.3 Non-functional requirements

Table 8.3 lists the non-functional requirements entailed in the application, in addition to their priorities and status of completion. Non-functional requirements are used to define the attributes or qualities of the application. Since this thesis is mostly involved with the design and development of the user interface of the application, non-functional requirements were not many.

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Priority</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>F11</td>
<td>Patients should be able to enter their pain and mood levels.</td>
<td>Medium</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Priority</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF1</td>
<td>The application should still work even if the connection was lost between the pebble and the tablet.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>NF2</td>
<td>The user need not to interact with the product for it to function.</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>NF3</td>
<td>The screen should always be on without dimming.</td>
<td>High</td>
<td>Yes</td>
</tr>
</tbody>
</table>
8.3 Application view models

8.3.1 Physical view

The physical view presented in Figure 8-1 simply shows the basic concept of the motivational tool and how prospective users will be able to retrieve visualised feedback of the patient’s physical activity levels. The sensor retrieves measurements of the patient’s movements and then sends them to the application to be processed using a Bluetooth network. The android application then processes the data upon retrieval to recognise the activity using a machine algorithm, and then shows the progress in a visual format with a bar chart showing how much time was spent on each activity. These results then get converted to activity points. The user will track the patient’s progress in accordance to the preset daily goal.

Figure 8-1: Physical view diagram
8.3.2 Logical view

Figure 8-2 represents what occurs to the user interface once the application has retrieved a new measurement from the Pebble watch. On the retrieval of a new measurement, this measurement is sent to the Bridge class which connects the interface to the machine algorithm that recognises the activity. The bridge class has been instantiated in the Application class thus it can be retrieved and modified from any class or activity in the application. The application then identifies the physical activity and then sends back a string with the last recognised activity. The Measure class, which is the main activity of this application, then invokes the method render() on the ChartAdapter that’s designated for the activity bar chart and the PieChart.Adapter which is responsible for showing the activity points. These charts then get refreshed and repainted using the new measurements retrieved from the Bridge class.

![Sequence diagram]

Figure 8-2: Sequence diagram

8.4 Internet of Things

As previously mentioned, Internet of Things is defined as the network of objects that enables the transfer of data from one object to the other without requiring human interaction. This type of connection between these objects is associated with machine-to-machine (M2M) communication that is smart enough to work without human-to-
human or human-to-computer interaction. This project was developed with IoT’s concept in mind in order to build a system that allows the automatic retrieval of raw accelerometer data retrieved from the sensor applied on patients using an android tablet that has already established a connection with that specific sensor.

8.4.1 Retrieving Data from the Sensor

As previously mentioned in Chapter 6, the Pebble watch was chosen for this project due to its open SDK, water resistance feature and long lasting battery. In order to send acceleration measurements from the Pebble to the Android application, one of the team members of this project has developed a program written in C and uploaded it to the watch. This program was used to send acceleration data in batches every minute to reduce the battery consumption.

8.5 Machine Learning Algorithm

Machine learning is defined as the "implementation of computer software that can learn autonomously" [23]. Another team member used machine learning algorithms in this project in order to identify the movements performed by the patients. The classification of data has been tested with four different machine learning algorithms (discriminant analysis, K-nearest neighbour, Naive Bayes and Support Vector Machine) in order to identify which one should be used for this project. After doing a comparison among these machine learning algorithms, support vector machine gave the best results, and hence it was used for this project.

8.5.1 Support Vector Machine (SVM)

Support vector machines have been used for pattern classification, which entails classifying a certain object into one of the given categories, also known as classes [1]. They are supervised learning models that recognise patterns and analyse data. The reason behind using these supervised learning models was to recognise the activity that was performed by the patient. Thus, in the beginning parts of the project, we trained the algorithm by recording patients while standing, sitting, being active and inactive. Each activity is represented by a set of training examples. Given a set of training examples, each linked to one of the four categories used in this project
(standing, sitting, active and inactive), a support vector machine training algorithm builds a model that designates new data into one of the preset categories. As a result, when new data has been retrieved from the sensor, it gets processed and then mapped into a space that belongs to a certain category (e.g. active).

8.6 Database

The main incentive of having a database for our motivational tool was to be able to store data recorded from patients in an organised way.

In the beginning phases of the development of our product, we locally saved the training examples mentioned in the previous section by storing the measurements retrieved from the pebble’s accelerometer as .CSV files. During the development process, a "training" interface was created to allow the addition and storage of data collected from the accelerometer to train the support vector machine by adding more data sets. Through this interface shown in Figure 8-3, the user was able to create new training sets, record her or his movements and then save them into a folder on the tablet’s local disk.

As shown in Figure 8-4, once a connection has been established with the sensor (pebble), the user is able to create a new set with the activity that she or he wants to record (such as walking, standing, jumping.. etc). Pressing the button "record" on the application will enable the android application to retrieve data from the sensor. Data logging receiver then gets instantiated to start logging data from the pebble. The measurements received at this point keep getting added to a local array. Once the save set button is pressed, the newly recorded measurements get written to a .CSV file saved in the tablet’s local storage inside a folder with the name of the set.

The final evaluation of the motivational tool discussed in Section 10.1 required a functioning database to locally store the patients’ measurements on the Android tablet. Consequently, a NoSQL database has been implemented by another team member to handle the patient’s data.

8.6.1 NoSQL Database

The use of NoSQL databases has been rapidly increasing in recent years due to many reasons. Instead of storing data in relational table schemes such as SQL (Structured Query Language), NoSQL (Not only SQL) databases are created in a way that allows
Figure 8-3: Interface created for training the machine algorithm

Figure 8-4: Primitive design of the interface used for training the support vector machine used in this project
the addition of data without a predefined schema. Thus, this advantage makes this type of database very adequate for applications that are created with an agile approach, as any changes to the structure of the database such as adding a new column, does not affect the existing stored data, making it easy to do changes to the project throughout the development without the need for creating a whole new structure for the database [4, p. 1].

The reason behind the adoption of a NoSQL database instead of a relational database for this project was because of the agile iterative approach that was applied in the development. The requirements of the project kept changing throughout the way as with the end of each sprint, usability testing and interviews with prospective users including patients were conducted that resulted in changes in the requirements and the demands of the product and the design of the system. For a system that is being developed in a user-centric approach, the system is expected to go through iterative changes rather than developing in a waterfall approach that is not quite adaptable to the users’ needs. In addition, the created motivational tool had to be scalable and allow a large number of users to use the product at the same time for future versions of the product. Moreover, performance of accessing the database was also another factor that was taken into consideration while deciding on which database to use; the speed of accessing data (throughput) in a NoSQL database is faster than an SQL database [6].

8.6.2 Couchbase Lite

According to Getting Started with Couchbase Server (2013), Couchbase Server is defined as "a distributed, document-based database that is part of the NoSQL database movement [4, p. 1]". This server is a NoSQL distributed database that provides high performance with an unstructured model of data that allows flexibility in the data structure.

Couchbase Lite, a mobile version of Couchbase database has been used for the database of the application. This database is deployed as a document database, which makes storing and retrieving data very simple, efficient and fast. In addition, a structure need not to be created prior to storing data. Another reason for using this database for our project is because of its elasticity. Due to the changing demands of the software, elasticity in the data structure of the database is needed to allow for expansion.
The information is stored in a document (the value) with an ID that identifies it (the key). The document is stored by sending the document data that contains the data that you want to store along with the document ID that this data belongs to. Retrieving data works in a similar way, you only need to provide the document ID and that will retrieve the document data under that ID.

8.6.3 Implementation Iteration 1

After four iterations of the digital design, usability testing and interviews, the first iteration of the functioning interface was developed. Interviews were then conducted on the 22nd of April, 2015 to evaluate the first iteration of the developed application. Section C.5 in the Appendix shows some screenshots of the software that was shown to patients during these interviews. At this point, the product was developed without a local database. The interface developed in this iteration was able to show patients their current activity levels using a bar chart that shows the time spent on each activity (standing, sitting, active and inactive). Pebble watch was used to retrieve measurements, and these measurements were then processed using a machine algorithm to detect which activity is being performed. The retrieved measurements were then visualised on the screen. In addition, Activity Points were developed in this iteration using a circular pie chart showing patients their daily progress based on a goal set by the physiotherapist.

To evaluate the first implemented version of the application, three patients were interviewed. In every session, patients were first given a brief overview of the concept of the application and its aims in motivating patients to move more, and were then asked to give us their opinion.

Questions

This interview was mainly focused on evaluating the following points:

- Were you a physically active person before being diagnosed?

- If you were to have a sensor on your body that would quantify your activity levels, what is your preferred location for the sensor placement?

- How well do you understand this interface? What do you think of the activity bar chart and activity points?
## Results

Table 8.4: Results from Interviewing Patients

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOB</td>
<td>1948</td>
<td>1958</td>
<td>1954</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Previous activity levels</td>
<td>Used to work out a few times per week. Used to dance as well.</td>
<td>Active at his job but doesn’t work out</td>
<td>was not a person who regularly trains, but used to cycle and run a lot</td>
</tr>
<tr>
<td>Preferred location of sensor</td>
<td>Her first preferred choice was putting it on the ankle. Her main problem was having red spots caused by her sensitive skin</td>
<td>Okay with having it on his chest and arm, but thought that having it on the leg might be difficult as it is out of reach</td>
<td>Not chest because of the discomfort, he liked having it on the arm</td>
</tr>
<tr>
<td>Activity Points</td>
<td>Understood the concepts but thought m means meter and not minutes</td>
<td>He did not like the concept as he likes to move on his own without anyone telling him</td>
<td>Got confused about the m on the chart (did not know if it refers to minutes or meters)</td>
</tr>
<tr>
<td>What makes you more motivated</td>
<td>To get better</td>
<td>To get better and get discharged earlier</td>
<td></td>
</tr>
<tr>
<td>Some comments</td>
<td>She got happy about the idea as she often sits and lies down while watching tv</td>
<td>Did not like the concept as a whole.</td>
<td>Had a problem with stem cell transplantation. Has sore hands, back and legs so it’s hard for him to move</td>
</tr>
</tbody>
</table>
Recommended Changes

After getting feedback from patients about the product and its interface, the following recommendations were created to enhance the overall quality and ease of use of the application.

- Increase the size and contrast of the text within the application.
- The value on each bar should be converted to 00h 00m.
- Due to its ambiguity, the letter ‘m’ on the y-axis should be changed so that it represents time and not distance.

8.6.4 Implementation Iteration 2

After getting feedback from patients about the first developed version of the application, the final iteration was developed. This iteration included a database which stores the patient’s physical activity levels locally on the Android tablet. In addition, a button has been added to the main screen which navigates to an activity that asks the patient about her or his pain and mood. The reason for including this functionality was to help the staff get a better understanding of the changes that the patient is passing through. Some adjustments were made in this iteration to make the application ready for a one-day testing with patients.

Although the application was not fully completed to be implemented in hospital clinics, it was good enough to be tested on patients and answer the questions that were set for this research.
Part IV

Results
Chapter 9

Results

CTMH wanted to develop a motivational tool that is targeted to help patients move more by showing them quantified information about their physical activity levels. Based on interviews, observations and user studies, an initial concept of the application was created, which resulted in the development of the final application discussed below. The major result of this thesis project was the design and development of the GUI of the application in a user-centric way. The final prototype of this project was intended to be utilised in a study that will be conducted at the haematology clinic at Karolinska University hospital.

9.1 GUI and functionality

The main purpose of this application is to give a brief overview of the patients’ activity levels in order to serve as a motivating factor for patients to increase their physical activity levels and provide valuable information that can help physiotherapists and doctors know their patients in a better way. Figure C-12 provides the resulting interface that was tested on patients during a one-hour testing. The evaluation of this test is discussed in the next chapter. The GUI is previewed in full screen in order to restrict the user from navigating away from the application, and the tablet is set to be located on a holder attached to the patient’s table.

Activity Bar Chart

To cover the requirement that entails showing patients their activity levels in a lucid way, we have decided to add a vertical bar chart that provides information about the
time spent on each activity. Once the data retrieved from the pebble gets processed through the machine learning algorithm and the activity gets recognised, the chart updates its view with the new data. The y-axis represents time, which is considered the dependent variable which represents the output. Whereas the x-axis represents each activity with three items: the icon that represents this activity, the name of the activity, and the weight that it holds. The weight of each activity is a number that depicts its value. For instance, Figure C-12 shows that being Active (aktiv in Swedish) has a weight of 6, which means that for every minute you are active, you gain 6 activity points. These weights were based on the importance of each activity. The colour of each activity’s bar was carefully chosen based on the activity’s value and meaning. For example, aktiv is characterised with a green colour which signifies life, nature and hope. Moreover, blue has been chosen for the standing activity (Stående) due to its symbolisation of stability.

**Activity Points**

As previously discussed in earlier chapters, in order to evaluate the overall performance of the patient, the concept of activity points was introduced. Activity points
are simple numbers that are calculated based on the patients’ activities. Each activity has a different weight represented next to the label’s name that relates to the importance of this specific activity. Based on interviews with patients, it has been decided to show the activity points concept in a pie chart that shows the patients’ progress with a percentage that lies in the middle of the chart. This percentage is based on how far the patient is from achieving her or his goals that are set by the physiotherapist.

**Setting goals**

Another important functionality is to let the physiotherapist choose a specific goal for every patient, as each patient that comes to the clinic has a specific case, thus the patients’ conditions, fitness and other factors contribute to the physiotherapist’s decision in setting a specific goal. To access the screen that allows you to set a specific goal for the patient, the user has to tap on the screen five times with five fingers, and then the action bar appears. From there, the user can press "set goal" which lies in the action bar’s menu.

![Figure 9-2: Setting the patient’s goal for today](image)

Latest measurement: Aktiv at 2015/05/19 15:22:35

Aktivitetspoäng

Dagens mål: 300 p

Huvudmål: 104 p

34%

Inaktiv x0  Sittande x1  Stående x2  Aktiv x6

Tid

0  1 h 14 m

0  2 h

Figure 9-2: Setting the patient’s goal for today
Pain and mood level

An important feature which was added to improve the staff’s knowledge of patients was this screen that asks the patient to enter her or his pain and mood level. This screen can be accessed by tapping the smiley button which lies on the bottom right of the screen. The first question asks about the patient’s pain intensity using a Visual Analog Scale (VAS). The second question asks about the patient’s mood. This will help indicate the correlation between the patient’s activity levels and her or his pain and mood levels.

![Image](image.png)

Figure 9-3: Pain and mood levels
Chapter 10

Evaluation and Conclusion

This chapter concludes the project with an evaluation of the resulting application and a conclusion that summarises this thesis. Based on the evaluation criteria mentioned in the introduction, the research and development methodology is evaluated in the beginning of this chapter. This is then followed by the strengths and weaknesses of the project and answers to the research questions. Finally, further work is provided and the project ends with a conclusion that summarises this report.

10.1 Methodology

As previously discussed in Section 3.1, design science research was chosen as the research methodology for this project as it fitted well with the project’s requirements. The research is evaluated with the following methods introduced in Section 3.3.

Experimental - Controlled

To assess the qualities, potential, usability and acceptance of the application in the patients’ hospital rooms, we have conducted a one-day testing with six patients staying at the haematology department at Karolinska Hospital in a controlled environment. After being introduced to the concept of the application and its purpose, patients who participated in this experiment were asked to wear the Pebble watch (with detached bands) on their chest for 8 hours. The Pebble was attached to the patient’s chest using special patches that were made for sensitive skin. The final version of the application was installed on the Android tablet which was attached to a table next to the patient’s bed using a tablet holder. Five out of six patients were able to
complete their daily goal which was set as 300 activity points. Furthermore, patients found no difficulty in entering their pain and mood levels during the testing session. It was observed that patients felt more motivated to be active in order to see their progress on the screen. Some patients were also seen walking outside their rooms. This illustrates the potential usefulness of this tool as a motivational source for cancer patients. The results of the interviews that were conducted after the one-day testing are listed in the following table.

Table 10.1: Questions and answers from patients after the one-day testing. Patients were asked to answer a number between 1-5 (1 being the worst and 5 being the best)

<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
<th>Patient 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender and data of birth</td>
<td>Female 1979</td>
<td>Female 1946</td>
<td>Male 1959</td>
<td>Male 1943</td>
<td>Male 1951</td>
</tr>
<tr>
<td>Did you understand the activity point concept?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>How accurate was the classification?</td>
<td>5</td>
<td>3.5</td>
<td>3.5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>How motivated were you to increase your physical activity?</td>
<td>3</td>
<td>5</td>
<td>2.5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>How comfortable was the sensor?</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>If this product was available now, would you like to have it?</td>
<td>Yes</td>
<td>Yes</td>
<td>Maybe</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Experimental - Simulation**

A simulation mode was added to the application to enable testing in earlier stages of the project and present the application’s functionality in interviews. Simulation mode triggers the retrieval of fake measurements in the application without the need to have a connection with the pebble.
Testing - Functional Black Box Testing

The functionality of the application was tested using black box testing to verify if the requirements of this project were accomplished or not. The results of this testing can be found in Section 8.2.

Descriptive - Informed Argument

The artifact’s utility has been assessed based on the research conducted in this paper that created a need for having a motivational tool that can help patients increase their physical activity to make them healthier and reduce their hospitalisation time. Chapter 1 describes the motivation for having such a device at hospital clinics, and Chapter 5 is dedicated to discuss similar tools used to help treating patients. In addition, Chapter 7 explains the iterations and the design decisions. What also adds to the argument is patients’ and staff’s positive response towards the application based on usability testing, interviews and observations.

10.2 Design principles

This section describes how the following design principles were used while designing and developing the application.

10.2.1 Jakob Nielson’s 10 usability heuristics

1. *Visibility of system status*
   
   To keep the user informed about what is going on, the screen showing the patient’s activities gets updated whenever the android application receives measurements from the pebble. This results in appropriate feedback within a reasonable amount of time. The application that was installed on the pebble was set to send the data in batches every 1 minute.

2. *Match between system and the real world*
   
   The icons that represent each activity were designed in such a way to relate to the actual activity in the real world. For instance, the "sitting" activity was represented by an icon of a person sitting on a chair. Using usability testing, we strived to ensure that users are still able to understand the icons without reading the labels.
3. User control and freedom
The final product of this project did not involve a lot of interaction with patients and thus this was not an issue. It is noteworthy to mention that it was vital to make sure that the patient is not able to close the application. This was solved by adding a software that makes our application fully immersive on the screen without showing a status bar or a navigation bar.

4. Consistency and standards
There were no noticeable consistency and standards problems in the design.

5. Error prevention
There was a minimum need for having error prevention due to the lack of full interaction between the user and the application, hence this was not considered a major issue while evaluating the application’s usability.

6. Recognition rather than recall
The user’s memory load is quite minimum with the interface chosen for this application as the information provided can be visible at all times, without the need to remember information from one part of the system to another. Nevertheless, this usability guideline should be carefully taken into consideration once other screens are added to the application.

7. Flexibility and efficiency of use
Due to the lack of interactions between patients and the application, having accelerators that would allow users to tailor frequent actions was unnecessary.

8. Aesthetic and minimalist design
All information provided by the interface contains information that are relevant to the function that this application serves.

9. Help users recognise, diagnose, and recover from errors
If the pebble stops sending measurements to the tablet, the user is not well informed with the current version of the application. However, this problem can be tackled by providing a notification that informs the user that the tablet is not receiving any data from the pebble due to a certain error.

10. Help and documentation
Documentation was not necessary for this application due to its self-explanatory
10.3 Strengths and weaknesses

Strengths

The main strength of this thesis project is the Android application that illustrates the importance of having a motivational tool that can motivate patients to move more by showing instant feedback on their activities. We were not able to find a similar motivational tool in the market or an application that detects patients’ activities in the way that this application does, which makes this application unique. Another strength is the user-centred development that this project has gone through to ensure having a usable application that can be easily understood by users. The user study helped us in understanding the prospective users and developing something that can easily be used in such an environment. Moreover, all qualitative and quantitative feedback gained from observations, usability testing and interviews contributed in the development of this application. In addition, the potential of this application was proven by the positive feedback gained by patients, physiotherapists and doctors at the haematology clinic. This application can be further developed to be implemented in patients’ rooms to increase their motivation and help them get better in a shorter period of time, which would be cost-effective for public hospitals and have a great impact on patients’ quality of life.

Weaknesses

Due to limited time and resources, a preexisting wearable device that was available in the market was chosen to be used for retrieving data from the built-in accelerometer. The main purpose of having an accelerometer in this project was to retrieve XYZ measurements and process them to recognise the activity performed by the patient. Current wearable devices often have more sensors than just an accelerometer, thus it is highly advisable to design and develop a brand new wearable device that encompasses a sensor with an open platform that provides open access to the retrieved data. Moreover, it was quite difficult to engage prospective users in the design and development stage. Each usability testing session was conducted with an average of three to
four participants, which might not have been enough. Thus, these sessions could be more accurate and collect more constructive qualitative feedback if a minimum of five participants were involved in every conducted test. Finding patients who were willing to participate in usability testing and interviews was difficult as cancer patients are often tired and weary. In addition, the final application of this project was considered to be only a proof-of-concept and was not ready to be fully implemented in hospital rooms. Further development and improvement to the product can help make this product sellable to hospitals.

10.4 Answering research questions

1. What are the existing wearable devices that encompass built-in sensors that can be used in a hospital setting to retrieve data such as body movements and heart rate from patients?
   
   This question has been answered by going through a number of wearable devices that have built-in sensors discussed in Chapter 6. A criteria presented in Section 8.3 has been created to evaluate each device to make sure that the chosen device can be tested and used in hospitals for the long run without interfering with the patients’ care. We have eventually chosen to use the Pebble watch for this project due to its water resistance features and its open platform, thus we were able to retrieve measurements from the built-in accelerometer using a bluetooth connection. The pebble was tested while being strapped on the patient’s chest without the arm bands.

2. What are the current available motivational tools that motivate patients to move more?
   
   The reviewed applications have given us an inspiration to how to develop an application that can involve patients in their treatments. Also, traditional motivational methods were investigated by questioning doctors and physiotherapists about the current way of motivating cancer patients to follow the exercises provided by the physiotherapists. Furthermore, the current motivational tools, digital and nondigital, also helped us in the development of this tool.

3. How will the activity levels of each patient be represented on the tablet to motivate patients?
In this project, it was highly important to focus on the usability of the application and make sure that all patients are able to understand its purpose without any effort. A number of design iterations were conducted to make that possible. This methodology was inspired by Jakob Nielson’s statement: "it is virtually impossible to design a user interface that has no usability problems from the start" [32]. Steady refinements of the user interface were done based on user testing, interviews, observations and other evaluation methods to find a proper way to present the patients’ activity levels on the tablet. This methodology resulted in having an application that shows patients the time spent on each activity using a bar chart on the left part of the screen and a circular progress chart that depicts the progress of each patient for that specific day. The reason behind adding a concept of "Activity Points" was to give patients a goal that they can strive to achieve everyday. The final one-day testing suggested that patients get rewarded and felt happier when they reached the goals that were set for them.

4. How usable is this application for physiotherapists, doctors and patients?

In order to test the application’s usability with prospective users, we have conducted several usability testing sessions and interviews with patients which resulted in several refinements of the interface to increase its usability as previously discussed. Moreover, we wanted to know the reaction of patients and the clinic for having such a system for patients who are willing to be involved in such a project. Through interviews, observations and usability testing, it has been proven that the clinic showed excitement and involvement about using this application as a daily practice. The one-day testing session has shown that this application has a great potential in this domain. Not only does it help patients be more motivated to be active, but it also gives a better overview of the patients’ performance and abilities to staff members (specially physiotherapists), which helps them understand and evaluate patients in an improved way.

10.5 Reflections

This section describes the reflections upon some elements that were experienced during the project.
Iterations

A single attempt to design an interface is virtually impossible, and thus we have decided to conduct as many iterations as possible within the limited time that we had. Four design iterations were conducted in this project. And then when the product was ready to be developed, we decided to switch from digital designs to actual implementation of the product. After two implementation iterations, we performed the one-day testing session to evaluate the final prototype and its use. Although we aimed to make the application more complete for the final prototype, we managed to implement the software enough to answer our research questions.

Future potential of this prototype

The main aim of this thesis project was to design and develop a prototype that quantifies the patients’ activities and represent them in a visual way. The response from the clinic and patients were mostly positive during the interviews, usability testing, and the final one-day testing session. We believe that the biggest contribution of this application is that we proved the potential of having such a system implemented in patients’ rooms. This certainly proves a great potential for proceeding with the development of this prototype so that it can be placed in hospital rooms to improve patients’ quality of life and help staff members evaluate their patients in a better way.

10.6 Future Work

This section describes the recommendations for future development and research.

Future Study at a clinic

In order to confirm the ability of this motivational tool to motivate cancer patients to increase their physical activity levels, a study is going to be conducted at the haematology clinic at Karolinska University Hospital in Huddinge, Sweden. The current suggested study design plan is to conduct a crossover study with patients who are expected to stay at the hospital for 22-28 days. According to Study Design and Statistical Analysis: A Practical Guide for Clinicians, a crossover study is when "subjects are randomised to one group and then switched to the other group at a specified time" [27, p. 18]. This way two groups of patients are needed to participate
in the study. One group of patients would receive the solution (a sensor and a tablet with the motivational tool installed) for a specified amount of time, whereas the other group does not. After a specified time, these groups will switch so that the group that did not get exposed to the solution gets exposed, and the solution will be taken away from the group that had the solution. By studying an adequate number of patients, it might be feasible to answer a new research question: "Can a motivational tool that quantifies patients’ movements motivate patients to increase their physical activity?".

**Database**

Allowing the staff to get access to patients’ activity levels is highly important for the next version of this motivational tool. Nevertheless, due to limited time and resources, this was not achievable in this project. Creating a centralised system that allows physiotherapists and doctors to get an overview of the performance of all patients using a web interface (with cloud storage instead of local storage) would certainly help the staff know patients in a better way, and the physiotherapist will be able to evaluate all patients at once.

Moreover, the software built for this study was developed as a single project and was not integrated with the centralised database that has patients’ records. As a result, it would be a better solution if the software was rebuilt to combine patients’ records with the data retrieved using this application.

**Explore and integrate other IoT devices**

- The Pebble Watch was used in this project due to a number of factors discussed in earlier chapters, but exploring other devices or even creating a standalone sensor that has an accelerometer can be more useful and cost-effective for this project.

- The addition of a Kinect Camera could allow for a better recognition of the body’s movements and thus could increase the accuracy of this product and recognise more type of activities.

- Having more than one sensor on the patient increases the number of measurements retrieved and therefore there is a chance of enhancing the accuracy of physical activity recognition. As a result, a research to confirm the effectiveness of adding additional sensor(s) could be performed.
New Features

- Adding a feature that would allow physiotherapists to add specific exercise programs for patients to let physiotherapists know if patients have actually performed the exercises they were supposed to do.

- Allowing patients to navigate between different days to see the changes in their performance.

- Adding a history view that shows the patient an overview of their performance during the past week.

Eye Tracking

In order to evaluate the use of the application and patients’ interests, it could be beneficial to evaluate how much time each patient spends using the application. This can be achieved using an eye tracking function that detects if the patient is looking at the screen or not. This can be implemented using OpenCV library for Android.

Localization / Internationalization

The current version of the motivational tool displays all information in Swedish only as it was implemented to be tested on patients at Karolinska Institutet’s hospital that mostly has Swedish patients; nevertheless, making it available in any language would increase the range of users who can use this tool.

Education

It would be useful to inform patients about the importance of exercise and physical activity and how it can change their lives on the app. Consequently, personalised education according to the diagnosed case could be useful for a future iteration of the product.
10.7 Conclusion

The purpose of this research project was to design and develop an interface for a system that will quantify patients’ daily activity levels, which will in turn motivate them to exercise more frequently. A literature review was conducted about existing technologies that are able to retrieve data used for activity recognition, and the Pebble watch was chosen to be used for this project due to its open platform and water resistance feature.

By testing the developed prototype through iterations on Android tablets in hospital rooms, we have illustrated the potential of developing a complete system that can be implemented in hospital rooms to help patients be more motivated to be physically active, which counteracts the body’s breakdown resulting in a shorter hospitalisation period.

One of our test users who was being treated at the hospital for Leukaemia said that this type of program would be perfect for her to combat her illness and be able to run in the Boston marathon one day. This was one of the factors that helped confirm the potential of our application in terms of motivating patients to become healthier. Nevertheless, despite the promising motivational tool that was created for this project, the project’s limitations raised the need for conducting a scientific study to assess the prototype’s capability of increasing patients’ physical activity levels after further development of the system.
Part V

Appendices
Appendix A

Personas
### Table A.1: Patient 1

<table>
<thead>
<tr>
<th>Gender</th>
<th>male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>50’s</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>high</td>
</tr>
<tr>
<td>Description</td>
<td>Patient 1 has not gotten any physical therapy prior to our visit. The physiologist briefly explained to him what the treatment entails and gave him some advice about the exercises that he will need to do in order to overcome the negative results of the treatment (such as getting tired and weary). The physiologist encouraged him to be exercising for at least 30 minutes per day and walk as much as possible if he’s capable of doing so. Nevertheless, the physiotherapist warned him about exercising with low haemoglobin levels as this will increase the likelihood of bleeding. The patient was in good shape and positive about the exercise plan that he will need to perform during the treatment.</td>
</tr>
<tr>
<td>Goals</td>
<td>Stay healthy and keep exercising even after getting the chemotherapy treatment, feel better as soon as possible and get out of the hospital as early as possible.</td>
</tr>
</tbody>
</table>

### Table A.2: Patient 2

<table>
<thead>
<tr>
<th>Gender</th>
<th>female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>70’s</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>low</td>
</tr>
<tr>
<td>Description</td>
<td>Patient 2 was extremely weak and was going through a lot of pain. She was also vulnerable to infections. Her platelets levels were very low, and she has been suffering from bleedings the previous day. Also, her haemoglobin levels were very low.</td>
</tr>
<tr>
<td>Goals</td>
<td>Avoid the physiologist to avoid doing any exercise and feel better as soon as possible in order to get out of the hospital.</td>
</tr>
</tbody>
</table>
Patient 3 is diagnosed with lymphoma and is going to be treated with stem cell transplantation. He is an outdoor patient as his treatment hasn’t yet started. The main goal of his therapy is to strengthen his muscles around his neck, spine and arms to be in a better shape for the upcoming treatment and avoid bone fractures. His training is 3 times a week.

<table>
<thead>
<tr>
<th>Gender</th>
<th>male</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>20's</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>high</td>
</tr>
<tr>
<td>Description</td>
<td>Patient 3 is diagnosed with lymphoma and is going to be treated with stem cell transplantation. He is an outdoor patient as his treatment hasn’t yet started. The main goal of his therapy is to strengthen his muscles around his neck, spine and arms to be in a better shape for the upcoming treatment and avoid bone fractures. His training is 3 times a week.</td>
</tr>
<tr>
<td>Goals</td>
<td>Be in a better shape before his treatment and stay healthy after the treatment.</td>
</tr>
</tbody>
</table>
Patient 4 was admitted into the department after being in the intensive care unit due to infections caused by the chemotherapy. He is suffering from a kidney infection that is being treated with dialysis. The patient was asked to exercise by squeezing a stress ball by both hands. He showed some difficulty in doing this exercise. It was noticeable on his hand that he’s suffering from a decrease in muscle mass. The patient was then asked to sit upright on the bed with the help of the physiotherapist. He was capable of sitting upright for a small period of time before feeling too weary to maintain his position. The physiotherapist then helped him into getting into a lying position on the bed. Consecutively, she asked the patient to lift his hands upwards and then pull them downwards against the resistance provided by the physiotherapist. As a part of another exercise, he then pushed his hands outwards and then inwards against resistance. Similar exercises were then performed on his legs. Core exercises were also performed to strengthen his muscles and prepare him for recovery.

<table>
<thead>
<tr>
<th>Gender</th>
<th>male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>70’s</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>low</td>
</tr>
<tr>
<td>Description</td>
<td>Patient 4 was admitted into the department after being in the intensive care unit due to infections caused by the chemotherapy. He is suffering from a kidney infection that is being treated with dialysis. The patient was asked to exercise by squeezing a stress ball by both hands. He showed some difficulty in doing this exercise. It was noticeable on his hand that he’s suffering from a decrease in muscle mass. The patient was then asked to sit upright on the bed with the help of the physiotherapist. He was capable of sitting upright for a small period of time before feeling too weary to maintain his position. The physiotherapist then helped him into getting into a lying position on the bed. Consecutively, she asked the patient to lift his hands upwards and then pull them downwards against the resistance provided by the physiotherapist. As a part of another exercise, he then pushed his hands outwards and then inwards against resistance. Similar exercises were then performed on his legs. Core exercises were also performed to strengthen his muscles and prepare him for recovery.</td>
</tr>
<tr>
<td>Goals</td>
<td>Be able to sit up on his own, be able to get out of bed and move and get out of the hospital as early as possible.</td>
</tr>
</tbody>
</table>
Table A.5: Medical Doctor

<table>
<thead>
<tr>
<th>Gender</th>
<th>male</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>40’s</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>high</td>
</tr>
</tbody>
</table>

**Description**
The medical doctor who works at the haematology clinic is interested in knowing in how the patient is feeling before, during and after the treatment. He goes on rounds and checks patients everyday. Every morning, each doctor talks about the patients that she or his is responsible for with other doctors.

**Goals**
Help patients feel better so that they would be able to endure the treatment and get better, be able to evaluate the patient’s pain level and know more about the patient’s physical activity level.

Table A.6: Physiotherapist

<table>
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<th>Gender</th>
<th>female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>40’s</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>medium</td>
</tr>
</tbody>
</table>

**Description**
The physiotherapist is interested in knowing how patients are doing. It’s the physiotherapist’s role to ensure that patients’ stay physically healthy during their stay at the hospital.

**Goals**
Motivate the patient to exercise. Give patients exercise programs that they could follow. Evaluate if the patients are performing the activities that they are supposed to do to get better. Help patients during some exercises and movements.
Appendix B

Tables
<table>
<thead>
<tr>
<th>Wearable Device</th>
<th>Placement</th>
<th>Movement Sensor</th>
<th>Heart Rate Sensor</th>
<th>Battery Life</th>
<th>Charging Time</th>
<th>Memory</th>
<th>User-interaction</th>
<th>Water-resistance</th>
<th>Android Compatible</th>
<th>Raw Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitbit Surge</td>
<td>wrist</td>
<td>3D acc and Gyroscope</td>
<td>✅</td>
<td>7+ days</td>
<td>1-2 hours</td>
<td>7 days</td>
<td>square screen</td>
<td>to 5ATM</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Fitbit Charge HR</td>
<td>wrist</td>
<td>3D acc and Gyroscope</td>
<td>✅</td>
<td>5 days</td>
<td>1-2 hours</td>
<td>7 days</td>
<td>small OLED display</td>
<td>to 1ATM</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Microsoft Band</td>
<td>wrist</td>
<td>3D acc and Gyroscope</td>
<td>✅</td>
<td>48 hours</td>
<td>2 hours</td>
<td>64MB internal storage</td>
<td>AA size display</td>
<td>against sweat and splash</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Olive</td>
<td>wrist</td>
<td>3D acc</td>
<td>✗</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>LED indicator</td>
<td></td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Nike+ Fuel-Band SE</td>
<td>wrist</td>
<td>3D acc</td>
<td>✗</td>
<td>&lt; 4 days</td>
<td>3-4 hours</td>
<td>few weeks</td>
<td>100 dot LED display</td>
<td></td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Samsung Gear Live</td>
<td>wrist</td>
<td>accelerometer, gyroscope and compass</td>
<td>✅</td>
<td>1-2 days</td>
<td>2 hours</td>
<td>512MB RAM, 4GB Internal</td>
<td>1.63&quot; Super AMOLED screen</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Samsung Gear Fit</td>
<td>wrist</td>
<td>accelerometer and gyroscope</td>
<td>✅</td>
<td>up to 5 days</td>
<td>2 hours</td>
<td>4 GB internal storage</td>
<td>1.8&quot; curved Super AMOLED screen</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

*Continued on next page*
<table>
<thead>
<tr>
<th>Wearable Device</th>
<th>Placement</th>
<th>Movement Sensor</th>
<th>Heart Rate Sensor</th>
<th>Battery Life</th>
<th>Charging Time</th>
<th>Memory</th>
<th>User-interaction</th>
<th>Water-resistance</th>
<th>Android Compatible</th>
<th>Raw Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moto 360</td>
<td>wrist</td>
<td>9-axis accelerometer</td>
<td>✓</td>
<td>1 day</td>
<td>2 hours</td>
<td>5 GB internal storage</td>
<td>1.56&quot; screen</td>
<td>up to 1m immersion</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mio Fuse</td>
<td>wrist</td>
<td>pedometer</td>
<td>✓</td>
<td>7-10 hours</td>
<td>N/A</td>
<td>Offline storage of 2 weeks of daily activity data</td>
<td>LED Matrix screen</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Garmin Vivosmart</td>
<td>wrist</td>
<td>accelerometer</td>
<td>✓</td>
<td>up to 7 days</td>
<td>N/A</td>
<td>offline storage of 3 weeks</td>
<td>OLED Blacklit display</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Garmin Vivofit 2</td>
<td>wrist</td>
<td>accelerometer</td>
<td>✓</td>
<td>1 year</td>
<td>N/A</td>
<td>offline storage of 3 weeks</td>
<td>Segmented LCD</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>HxM / BioPatch</td>
<td>chest</td>
<td>accelerometer and gyroscope</td>
<td>✓</td>
<td>1 day</td>
<td>2 hours</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>✓ but paid SDK</td>
</tr>
<tr>
<td>Misfit Shine</td>
<td>anywhere</td>
<td>3-axis accelerometer</td>
<td>×</td>
<td>6 months</td>
<td>none</td>
<td>up to 30 days</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>MOTOACTV</td>
<td>wrist</td>
<td>accelerometer</td>
<td>✓</td>
<td>N/A</td>
<td>N/A</td>
<td>8 GB</td>
<td>1.6&quot; screen</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</table>

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<table>
<thead>
<tr>
<th>Wearable Device</th>
<th>Placement</th>
<th>Movement Sensor</th>
<th>Heart Rate Sensor</th>
<th>Battery Life</th>
<th>Charging Time</th>
<th>Memory</th>
<th>User-interaction</th>
<th>Water-resistance</th>
<th>Android Compatible</th>
<th>Raw Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellograph</td>
<td>wrist</td>
<td>accelerometer, gyroscope and magnetometer</td>
<td>✓</td>
<td>up to 7 days</td>
<td>1 hour</td>
<td>4 months of records</td>
<td>LCD screen</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Notch</td>
<td>anywhere</td>
<td>accelerometer and gyroscope</td>
<td>X</td>
<td>3 days</td>
<td>N/A</td>
<td>N/A</td>
<td>no screen</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LG LifeBand Touch</td>
<td>wrist</td>
<td>accelerometer and altimeter</td>
<td>✓</td>
<td>2-3 days</td>
<td>1-2 hours</td>
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<td>OLED Touch screen</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
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<td>Sony Smartband</td>
<td>wrist</td>
<td>accelerometer and gyroscope</td>
<td>X</td>
<td>5 days</td>
<td>1-2 hours</td>
<td>256kB internal embedded flash</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Jawbone Up 3</td>
<td>wrist</td>
<td>Tri-axis accelerometer</td>
<td>✓</td>
<td>7 days</td>
<td>100 minutes</td>
<td>up to 9 months</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Pebble</td>
<td>wrist but its bands are detachable</td>
<td>accelerometer and gyroscope</td>
<td>X</td>
<td>up to 7 days</td>
<td>2 hours</td>
<td>4 MiB (32 Mibit) flash</td>
<td>Screen with side buttons</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Angel Sensor</td>
<td>wrist</td>
<td>accelerometer and gyroscope</td>
<td>✓</td>
<td>1 day</td>
<td>1 hour</td>
<td>N/A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
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</table>

Continued on next page
<table>
<thead>
<tr>
<th>Wearable Device</th>
<th>Placement</th>
<th>Movement Sensor</th>
<th>Heart Rate Sensor</th>
<th>Battery Life</th>
<th>Charging Time</th>
<th>Memory</th>
<th>User-interaction</th>
<th>Water-resistance</th>
<th>Android Compatible</th>
<th>Raw Data</th>
</tr>
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<tbody>
<tr>
<td>Metaware</td>
<td>anywhere</td>
<td>accelerometer</td>
<td>✗</td>
<td>varies</td>
<td>varies</td>
<td>256 kB flash</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
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<td>GeneActiv</td>
<td>wrist</td>
<td>accelerometer</td>
<td>✗</td>
<td>N/A</td>
<td>N/A</td>
<td>0.5Gb of raw data</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Zwear</td>
<td>anywhere</td>
<td>accelerometer</td>
<td>✗</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Hexoskin</td>
<td>body</td>
<td>accelerometer</td>
<td>✓</td>
<td>14 hours</td>
<td>N/A</td>
<td>N/A</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Withings Pulse ox</td>
<td>anywhere</td>
<td>accelerometer</td>
<td>✓</td>
<td>10-12 days</td>
<td>1-2 hours</td>
<td>N/A</td>
<td>touch screen</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Lumo Lift</td>
<td>around the waist and gyroscope</td>
<td>accelerometer</td>
<td>✗</td>
<td>5-6 days</td>
<td>N/A</td>
<td>32mb of flash memory</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Lifetrak zone C410</td>
<td>wrist</td>
<td>pedometer</td>
<td>✓</td>
<td>one year</td>
<td>no charging</td>
<td>7 day memory</td>
<td>side buttons</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Appendix C

Interfaces

C.1 Design Iteration 1

Figure C-1: Daily View: the first screen that appears
Figure C-2: History View

Figure C-3: Mood/Pain input
C.2 Design iteration 2

Figure C-4: Daily View

Figure C-5: Mood/Pain input
C.3 Design iteration 3

Figure C-6: Daily View

C.4 Design iteration 4

Figure C-7: Concept 1
Figure C-8: Concept 2

Figure C-9: Concept 3
Figure C-10: Concept 4
Figure C-11: Daily view showing the patients’ current progress

Figure C-12: Setting the patient’s goal for today
Bibliography


[18] Bengt Göransson, Jan Gulliksen, and Inger Boivie. The usability design process - Integrating user-centered systems design in the software development process, 2003. ISSN 10774866.


